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NEW YORK, FEBRUARY, 1888.

A CORRESPONDENT writes us that about 40 years ago a pamphlet was published by a Mr. Payne describing a plan for a bridge across the East River at New York, and called by the inventor the "Flying Suspension Bridge." If any of our readers are possessed of a copy of that pamphlet, they would confer a favor on the Editor of the RAILROAD AND ENGINEERING JOURNAL by loaning it to him for a short time. The utmost care will be taken of it while in his possession.

OUR Northern neighbors have a right to feel a little proud this year, when one of the leading American technical societies and one of the leading railroad associations go to them for presiding officers. This is a kind of reciprocity to which no one can object, especially as Canada has always supplied faithful and valuable members to both societies.

THE Council of the Iron & Steel Institute of Great Britain has decided to hold the next autumn meeting of the Institute in the United States. A number of the prominent members of the Institute have already signified their intention of being present. The arrangements for the meeting have not yet been completed, but it will probably be held in September, and the headquarters of the Institute will be in Pittsburgh. The Iron & Steel Institute is the largest and most important body of a similar kind in the world, and at its meetings papers are usually read by practical and scientific men of the highest standing. Some of the members have visited this country before and are to some extent familiar with its resources; to many of them, however, this will be the first visit, and doubtless they will take advantage of it to study the country as far as their time and opportunities will permit.

This first meeting of a prominent association of English engineers on this side of the water will be a notable occurrence, and it will doubtless be made the occasion of many exchanges of courtesies by American societies.

A NEW source of petroleum supply, which may in time affect American trade with India and other Asiatic countries, has been found in the little-known country of Beluchistan, where the borings which have been in progress at Khatan are said to give indications of a large and constant supply. The new wells are at present remote from all except the most primitive means of transportation; but those who are familiar with the country say that there are few or no difficulties in the way of a pipe-line from the wells to the terminus of the Indian frontier railroad line. Of course the development of these wells will require time, but their connection with the outer world may be hastened somewhat from the fact that a supply of oil for fuel will be of great benefit to the military railroad which is now slowly finding its way into Afghanistan from India. On this line the supply of fuel is a difficult question, and the bringing of petroleum from Khatan by pipe would not only reduce the cost of operating it, but also provide it with the commercial traffic which it now lacks.

The length of the pipe-line required would be, it is stated, only about 65 miles, through a country rough and uneven, but presenting no formidable obstacles. A considerable quantity of the oil has already been brought from Khatan in barrels, and it is now being tested as to quality.

ACCORDING to the latest reported utterances of M. de Lesseps, the completion of the Panama Canal, which he has promised for 1890, is not to be that of the sea-level canal for which the plans provided originally. The present plan, he says, is to pass the section of greatest excavation by a temporary high level canal, to which ships are to have access through a series of huge iron locks at either end. These locks are to be built by M. Eiffel, the engineer who has designed and is building the 1,000-ft. iron tower on the Exposition ground in Paris. The high-level canal is to be 120 or 150 ft. (the height is variously given) above the sea-level. After this is opened, we are told, the excavation will be continued at the Culebra until the tide-level is finally reached. In other words, M. de Lesseps proposes to follow railroad practice, and use a sort of marine switchback until his permanent line is completed.

Whether this is practicable is not altogether clear. Two objections are suggested, the first that it will be difficult to find a supply of water for the 150-ft. level, and the other that the practicability of the proposed system of iron locks is not by any means established. Even if both these points be conceded, it is not at all certain that the work can be completed in two years, or that the diversion of the Chagres River can be completed so as to secure the western end of the canal from accident.

In this connection it may be noted that the French Government has refused to give the Canal Company permission to issue another lottery loan. It is announced, however, that bonds are to be issued on another basis.

THE only bill so far presented in Congress for the direct increase of the Navy is one providing for the construction of three gunboats or despatch boats of about 900 tons displacement, to have a speed of 13 knots. These are to be used specially as training ships, and are to take the place of the old vessels heretofore used for that purpose. Those vessels are of old style and construction and, moreover, will not last much longer without expensive repairs. A

training ship ought to represent the latest practice, if it is to serve properly the purpose for which it is intended.

IN selecting the names of the new cruisers for the Navy, Secretary Whitney has followed the practice of his predecessors, and has chosen those of the larger cities of the country. The *Atlanta*, *Boston*, *Chicago*, *Charleston*, *Baltimore*, and *Newark* had already been named, and now it is announced that the two cruisers under contract, heretofore known only as Nos. 4 and 5, are to be named *Philadelphia* and *San Francisco*.

In naming the new gunboats, however, the Secretary has begun a new series, and the *Concord*, the *Bennington*, and the *Yorktown* will commemorate the battles of the Revolution. The smaller gunboat is to be called the *Petrel*, apparently to give the *Dolphin* an aerial companion.

THE Zalinski dynamite gun has attracted much attention abroad as well as in this country, and has been the subject of much discussion among foreign naval authorities. The first actual order from Europe, we believe, is one from the Italian Government, which is for a gun capable of throwing a projectile weighing 600 lbs. This is to be used for experimental purposes; if successful, a number of the guns will probably be ordered.

THE Nordenfelt submarine torpedo boat, some trials of which are described elsewhere, is one of the most formidable vessels for coast and harbor defense yet built. For attack on a fleet the Nordenfelt boat is, apparently, free from most of the defects of the ordinary torpedo boat, and it would be extremely difficult, if not impossible, for an antagonist to injure her, if properly handled, simply for the reason that she cannot be seen when submerged, and presents a very small mark even when above water. The boat is, in effect, a submarine projectile which can be handled, turned, and made to strike just where it is wanted.

A BILL providing for the establishment of a naval reserve, or a naval militia, to include both ships and men, has been introduced in Congress, and is now in committee. Its provisions are very much in the line of the recommendations heretofore made in this direction by the Secretary of the Navy and Admiral Porter. The bill is apparently so well prepared, and is of such importance, that we give its provisions, almost in full, on another page.

The bill has attracted much attention, and it is to be noted that, while fault is found here and there with some of its details, the general principle seems to meet with approval from those interested in shipping both on the ocean and on the lakes.

THE steel rail production of the United States last year was the largest on record, reaching a total of 2,050,000 gross tons or 2,296,000 net tons. Much of this was, of course, absorbed by the great mileage of new road built, but the demand was swelled by the orders for renewals on old roads, which were, as usual in a prosperous year, greater than for several years past. Prices, however, were not maintained throughout the year, being at the close of the year $6 per ton below the opening of the year, and $7 below the highest point. Prices began to decline about the middle of the year, but fell slowly until October, when there was a sharp decline. By that time, however, the orders for the year had been substantially all placed. The output varied but little, that of the second half of the year being only a few thousand tons below the first. All the mills ran throughout the year pretty well up to their capacity, and with them, as with many other branches of manufacturing, 1887 was an exceptionally prosperous year.

THE new year opens for the steel rail mills very differently from the last. Just at present nearly all the mills are shut down, with no immediate prospect of opening. This state of things, however, is not the result of an absence of demand for rails, but of a difference of opinion as to prices. The makers claim that present prices are too low to afford a reasonable profit, and want to increase them, but buyers naturally do not take the same view, and the large orders which are generally placed early in the year have been so far withheld. This has led to a sort of dead-lock for the time, but this situation cannot be expected to last very long. The demand for rails for new road is, apparently, to be somewhat less this year than last, but the requirements for renewals and new work must still be large enough to afford a fair amount of work.

THE discussion of the project for building a bridge over the Hudson River at New York City has called out one definite plan for such a structure, which was presented to the American Society of Civil Engineers at a recent meeting by one of its members.

The merits of Mr. Lindenthal's plan need not be discussed here. There is no doubt that a good plan for a bridge can be had, if it is to be built. The chief trouble will be to secure such an agreement among the railroads which would use the bridge as will make it easy to raise the money needed. To do this will be the hardest part of the work.

THE most stupendous plan yet suggested is by a French engineer, who proposes to cross the English Channel from Ambleteuse to Folkestone by a bridge. The Channel at that point is about 25 miles wide, the depth of water varying from 40 to 200 ft. The plan provides for masonry piers rising some 35 ft. above the water, which are to carry lofty steel towers, the latter supporting the superstructure. The bridge spans are to be from 1,500 to 2,000 ft. long.

French papers say that the plan has advanced so far that a company has been formed and negotiations opened with English and French contractors, whose engineers are now considering the practicability of the work. Nothing is said, however, about the political reasons which were urged to defeat the Channel tunnel project, and which would seem to be quite as strong against a bridge.

Even if the bridge plan is practicable, its enormous cost makes it very doubtful whether it will be really undertaken by a private corporation. The English Channel will probably continue to be crossed by ships alone for a good many years to come.

THE number of accidents on the New York City railroads is surprisingly small, when all the conditions are considered. The reports of the city companies for 1887 give a total of 42 killed and 204 injured, against 31 killed and 164 hurt in 1886. The summary at hand does not state how many of these were passengers; probably a large proportion of them were not. While the city rail-

road passenger is generally exempt from the dangers of collision or derailment to which the traveler is exposed on steam railroads, he incurs certain risks in getting on or off the cars; there is also the danger to outsiders which always arises from the movement of vehicles in crowded thoroughfares. The returns, however, show that the street cars in New York run over fewer persons comparatively than other vehicles do.

GRADE crossings of highways and railroads receive considerable attention from the New York Railroad Commissioners in their last report. They call attention to the many serious accidents resulting from such crossings, and recommend legislation not only to prevent any increase in their number, but also to provide for its gradual decrease.

THE introduction of the block signal system on one division of the New York, New Haven & Hartford road is a notable advance made by a company which has always been exceedingly conservative, and slow to adopt improvements. The business of the road is so large that it is hard to see how such action could have been postponed much longer consistently with safety in operation. There are several roads which do a larger business, but few or none which have so many fast passenger trains and so great a passenger business.

It may be noted also that the New Haven road is to be added to the list of four-track roads, the first section of the new third and fourth tracks having recently been opened for business. In another year the four-track line will cover the most crowded portion of the line, and it is the intention to carry it over the whole of the road from New Rochelle Junction to New Haven.

IN England, as in this country, the railroad is to a very great extent superseding the canal as a means of transportation. Before railroads were built the country was supplied with a system of canals on which a large traffic was carried, but it appears that a number of these water-ways, including some which we would class among the more important, have begun to fall into a dilapidated condition. Recently special complaint has been made by English papers of the state of the Thames & Severn Canal, which, it appears, is so much out of repair that it is difficult for boats to get through it at all. The traffic of this canal has decreased in a few years from about 44,000 tons to less than 30,000 a year, and this falling off has so reduced the tolls that the income is entirely too small to keep the canal in order, while this dilapidation, of course, diminishes the income. It is also insinuated that this state of affairs is partly due to the influence of the railroad companies with which the canal competes as a carrier, and it is openly charged that the railroad influence has made the managers neglect their work.

While it is not probable that the canal, even if kept in the best of order, would take business away from the railroads, to a very large extent, the managers of the latter evidently appreciate its influence as a regulator of rates, and understand that the effect which its improvement would have upon their business would appear more in profits than in the total traffic. Our English friends are just waking up to this view of the question, and when they fully realize its importance, some practical steps may be taken for repairing and renewing the canals.

In France and Germany the importance of water-ways has always been recognized. In those countries inland navigation has been not only maintained but extended, even where the country is well supplied with railroads, the practice in this respect being widely different from the English.

THE English military railroad on the frontier of Afghanistan, which has been the occasion of much controversy both from a political and an engineering point of view, is to make a further advance of 15 miles. The importance of this section, however, is much greater than its length would indicate, for it includes the most difficult work on the entire line, and it is expected that from two to three years will be required to build it, owing to the length of tunneling needed. When this is finished some 70 miles of comparatively easy work will take the line to the Helmund River, within easy distance of Candahar.

The Russians, on the other hand, have their Central Asian line in such a position that it can be carried into Afghanistan by comparatively light work, and can reach Herat in less than a year, should it be necessary.

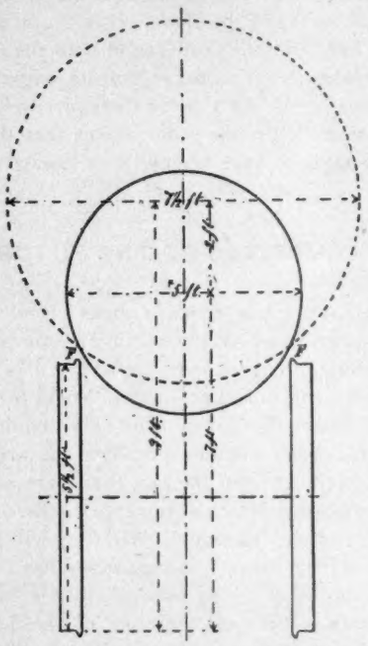
This contrast, and the advantage which the Russians would realize by it in case of war, is not a pleasant matter for the English, and the fault found with the Government is not diminished by the charge that its engineers had no adequate idea of the work to be done, or even of the best line to be taken, when the time arrived that the road was needed and ought to have been well on toward completion.

LOCOMOTIVES OF THE FUTURE.

A PARAGRAPH has recently been circulating in the daily press in which the public are informed that the largest passenger engine ever constructed is now being built in the Schenectady Locomotive Works for a Western road. The information given is not very definite, so that it is not possible to say whether it really is the largest passenger engine ever built; but the fact that there are examples of passenger engines which weigh 100,000 lbs. or over leads to reflection and anticipation. "How big will locomotives be in 50 years from now?" is a question that a mechanical engineer cannot help asking himself and his associates.

D. K. Clarke's "Recent Practice of the Locomotive" contains an engraving of a Mason locomotive, which was built about 30 years ago. It had 15×22-in. cylinders, 5½-ft. wheels, and a grate 4½ ft. long and 3 ft. 1¼ in. wide, giving a grate area of 14¼ square feet. This engine weighed about 55,000 or 56,000 lbs., and had about 800 square feet of heating surface. The Schenectady engine has a grate 8 ft.×3 ft. 6½ in., which gives a grate area of 28½ square feet. The heating surface is not given, but other passenger engines recently built have from 1,500 to 1,600 square feet, so that it may be said that within 30 years the size and weight of passenger engines has been nearly or quite doubled. Will this rate of increase continue, and in the year 1918 will there be passenger engines running which weigh 200,000 lbs. and over? There can be no doubt that the discoveries which made steel rails and steel tires possible, and their general introduction and use, gave a great stimulus to the increase in weight of rolling stock. Besides this the weight of rails on main line road has recently been increased. With a rail weighing 56 lbs. per yard, the maximum load per wheel which was safe and

economical was about 10,000 lbs. With 72-lbs. steel rails, loads of 15,000 and 16,000 lbs. per wheel are not unusual. The speed of locomotives, however, has not been increased in the same proportion as their weight. Thirty years ago 50 and 60 miles per hour was not an uncommon maximum speed. Now 60 and 70 is about as high as we get on any of our lines. The weight of trains has probably grown as much as that of locomotives, and, perhaps, will continue to increase. Supposing, then, that the problem was presented to day of making a passenger locomotive of double the weight and capacity of the largest now in use. That would mean an engine of somewhat over 200,000 lbs. in weight, with a grate surface of 55 to 60 square feet, and a boiler with 3,000 square feet of heating surface, and cylinders 27 or 28 in. diameter. Boilers 5 ft. in diameter are now not uncommon; 7½ ft. diameter would give about twice the sectional area. An eight-wheeled American engine, weighing 100,000 lbs., would have about 17,000 lbs. on each wheel. Double this weight, or 34,000 lbs. per wheel, would be enormous, and would require a very great increase in the weight of rails, and even then it would



be very doubtful if it could be carried without crushing both the tires and the rails. By distributing this load on six or eight wheels, the load per wheel would be 22,666 or 17,000 lbs., which is well within possible limits.

The experience of the last few years has shown that the height of the center of gravity is not a matter of so great importance as was formerly supposed. The first impression is that a high locomotive is as likely to upset as a high load of hay, and it takes a considerable time and some deductive reasoning to realize fully that the vertical inequalities and horizontal deviations from a straight line which a load of hay is expected to traverse bear somewhat the same relation to those of a railroad that high mountains do to the gentle undulations of prairie country, and therefore that an elevation of the center of gravity which would be disastrous to a load of hay may be quite safe for a locomotive on a railroad. Mr. Wootten had the courage of his convictions, and elevated the centers of the boilers of his locomotives 7 ft. 8 in. above the tops of the rails. The diagram herewith shows the height—7 ft.—which a boiler 5 ft. in diameter must be elevated above the rails, and the dotted line shows the position of a 7½ ft. boiler, with the same clearance of the flanges of the wheels at *F F*. It will be seen that the center of the large boiler must be 2 ft. higher than that of the small one, or 1 ft. 4 in. higher than Mr. Wootten's. When it is remembered, too, that the fire-box of Wootten's engine is on top of the frame and the cab on top of the boiler, it will be seen that if these and other parts were lowered the height of our hypothetical boiler may be quite practicable.

The experience with electric light engines during the past few years has indicated what may be done with high-speed engines, and in the light of that experience it may be that wheels of smaller diameters than 5½ ft. might be used, and the requisite speed be obtained by running the pistons at higher velocities than is the present practice with locomotives. This would permit the boilers to be lowered and the size of cylinders to be reduced, and, consequently, the reciprocating parts and wheels would all be smaller and lighter. This reduction in weight could then be put into the boiler, which is the source of all power.

It therefore seems quite probable that the size and capacity of locomotives will continue to increase, although it is likely that there will be some modifications of the present forms of construction which will permit of the use of larger fire-boxes, and of lowering those parts whose elevation with a changed construction will not be essential.

There are some sanguine people who also predict that the speed of locomotives will also be doubled in the shadowy future, into which none of us can see very far. Past experience has not shown an increase in speed corresponding with that of the weight and capacity of locomotives. The reason is not difficult to find. The capacity of a locomotive—that is, the load it can pull at a given speed—is proportionate to its weight; that is, an engine twice as heavy will pull a train of double the weight. There is a physical law which unfortunately prevents the fulfillment of the predictions of the sanguine prophets of speed—that is, that the resistance of trains increases as the square of the velocity—probably at even a higher ratio at high velocities; and what adds to the difficulty is that when the amount of work is thus increased it must be done in less time. Thus at 60 miles an hour the resistance is roughly twice as great as it is at 40 miles, and the work must be done in two-thirds of the time. This law stands in the way of an increase in speed beyond limits which are soon reached in practical service.

NEW YORK CITY PASSENGER TRAVEL.

THE management of the passenger movement of a large city is always a complex problem, the solution of which becomes continually more difficult as the growth of the city at once increases the number of people to be carried and the distances over which they have to pass. This is particularly the case in New York, where, on account of the shape of the city, the movement is nearly all in one direction and the distances are greater, and where the number of passengers is increased by the daily influx of a large suburban population. Probably there is no city in the world in which the number of persons using the public conveyances bears so large a proportion to the resident population.

The returns made to the Railroad Commission by the New York City railroad companies for the year ending September 30 last, when compared with those for the previous year, show some interesting facts.

The total number of passengers carried was as follows:

	1887.	1886.	Changes.	
Elevated (steam) railroads.....	158,963,232	115,109,591	Inc.,	43,853,641
Surface (horse) railroads.....	199,574,966	206,930,070	Dec.,	7,355,104
Total.....	358,538,198	322,039,661	Inc.,	36,498,537

A further examination of the figures may serve to explain, or, at least, to make clearer, some of the changes shown in this table.

The surface or horse railroad companies operating lines in the city are 18 in number. Ten of these operate lines running up-and-down town (as a New Yorker would say)—that is, in the direction of the main traffic; five have lines which do a mixed business, partly up-and-down town and partly across the city, while the remaining three are entirely cross-town lines—that is, they are short lines serving as feeders for the main lines of travel, and carrying people between them and the ferries and other points on the river fronts. The elevated railroad traffic is all up-and-down town.

The passengers carried by the surface roads were divided among the three classes of those lines indicated above, as follows:

	1887.	1886.	Changes.	
Up-and-down-town lines....	141,225,765	153,876,582	Dec.,	12,650,817
Lines with mixed business.....	50,968,161	47,908,575	Inc.,	3,059,586
Cross-town lines	7,381,040	5,144,913	Inc.,	2,236,127
Total.....	199,574,966	206,930,070	Dec.,	7,355,104

This statement shows very plainly that the loss of travel by the surface roads has been wholly in those lines which come into competition with the elevated roads.

Unfortunately, the companies in their reports give only the total number of passengers carried, so that it is impossible to give exact figures for the total movement of passengers up and down-town. The cross-town movement can only be reached approximately. If this be done, and that movement dropped entirely, the following table will give nearly the total travel of passengers on the main lines:

	1887.	1886.	Changes.	
Elevated roads ..	158,963,232	115,109,591	Inc.,	43,853,641
Surface roads....	175,204,439	185,815,632	Dec.,	10,611,193
Total.....	334,167,671	300,925,223	Inc.,	33,242,448

This shows to how great an extent the elevated lines last year took business from the surface roads. While the former increased their business over 38 per cent., the surface lines fell off 5¾ per cent., the increase in the total business being about 11 per cent.

Or, to put it in another form, the elevated lines not only took all the increase of business—over 33,000,000 passengers—but they also took over 10,600,000 more away from the surface lines.

In 1887 the elevated lines carried 47½ per cent. of the up-and-down-town travel, and the surface lines 52½, while in 1886 the proportions were 38 and 62 per cent., respectively.

The principal causes for these changes have doubtless been the reduction of fares on the elevated lines, which was last year for the first time in effect for a full year, and the fact that for several years past the main growth of the city has been in a section too far removed from the business centers to be readily accessible by horse cars. The reduction of fares was, of course, the chief reason. Some further causes might be suggested, but they are of minor importance, and probably no single one had much influence.

The total passenger travel last year thus reached an average of 981,200 per day, the average movement up-and-down town being on an average 915,300 per day. The total movement thus closely approaches a million a day; it will doubtless soon exceed that number. The number carried by the elevated lines averaged 435,500 a day.

That those lines are equal to the proper management of so large a traffic cannot truly be said. It must be remembered that the business is not at all evenly distributed; a large part of it is concentrated both as to time and direction, probably one-half being carried within less than six hours of the day. The present system of elevated roads will, doubtless, remain an important part of the transportation system of the city; they must necessarily serve their present purpose as the chief carriers for the longer distances for at least two or three years longer, until something better can be provided. With certain improvements—which there is not space here to indicate—they would serve for a longer time than that; but it is certain that additional means of transportation must be furnished the city before long. Whether additional elevated lines, viaduct or arcade lines, or underground tunnel roads are to give the needed relief is the question now open for discussion.

Unfortunately for the city, the decision of this question is, under present conditions, very likely to be governed by unworthy motives. The danger is that some temporary makeshift may be the result, and that the real work will be left to be all done over again a few years hence.

New Railroad Building in 1887.

THE tables presented by the Chicago *Railway Age*, which usually has the earliest reliable information on this point, show that there were built in the United States last year 12,700 miles of new railroad, a greater mileage than had ever before been constructed in one year. The highest point previously reached was in 1882, when 11,550 miles were built. This brings the total mileage of railroad in the country at the close of 1887 up to 151,000 miles in round figures.

The new mileage of last year was very unevenly distributed, the Southwest leading with 5,150 miles, and the Northwest following next with 3,150. The Southern States added 1,700 miles, the Middle West, 1,650, and the Pacific States, 650, while the additions in New England and the Middle States were very small. Fully 70 per cent. of the new mileage was west of the Mississippi. Three States had more than a thousand miles each: Kansas, 2,055; Nebraska, 1,100; and Texas, 1,055 miles.

These facts show the character of the railroad building of the year. It was chiefly or very largely in new country. The building of roads to parallel the Eastern trunk lines has been, for the present, abandoned, and the work is now to develop and occupy the new regions of the West and Southwest. Most of this last year was done by the older

companies, whose lines already touched the borders of the new country. The trouble is, perhaps, as is often the case in this kind of building, that it has been overdone, and that in the anxiety of the companies to cover territory and secure traffic, two or three lines have been built into districts where one would have been quite sufficient. Too much of this unprofitable work has been done in Nebraska, Kansas, and some other States, as a study of a complete map would show.

Perhaps the most important line completed during the year was the Oregon line of the Southern Pacific Company, which gives the Pacific coast of the United States for the first time rail communication from its northern to its southern extremity.

It is to be noted that a very large part of the new mileage has been in comparatively easy country, and that there has been little work which required the solution of difficult problems in engineering. The exceptions to this have been one or two lines in Colorado, the Northern Pacific line over the Cascade Mountains, the Oregon & California Line, and two lines which required the building of bridges over the Missouri and the Mississippi. On the whole, however, it may be said that last year's new mileage was largely made up of easy and therefore comparatively cheap road.

The present indications are that railroad extension reached its height in 1887. There are a number of new lines in progress and still incomplete, which will be finished this year, and there are others which will be begun, so that 1888 will show very respectable figures, but it is not likely that it will equal its immediate predecessor.

NEW PUBLICATIONS.

A Collection of Diagrams Representing the General Plan of Twenty-six Different Water-works: Contributed by Members of the New England Water-works Association. New York; published by the *Engineering and Building Record*.

This publication is the result of the labors of Messrs. William B. Sherman, of Providence, R. I., and Walter H. Richards, of New London, Conn., who, acting as a committee of the New England Water-works Association, collected the sketches.

These sketches, which were contributed by different members of the Association, are intended to represent, in a condensed form, general views of the plans and constructions of water-works under varying circumstances. They are, as might be expected, of varying merit, some giving really admirable condensations of plans and facts in forms which can readily be taken in at a glance; others require more study, and in a few the facts are somewhat imperfectly represented. All of them have merit, however, and will repay a careful study by the engineer who is interested in such matters.

Of the 26 cities whose water-works are here represented, 23 are in New England, the only ones outside of that section being those of New Orleans, Wilmington, N. C., and Knoxville, Tenn. The water-works are chiefly those of the smaller cities and towns, Boston and New Orleans being the only large cities included in the collection.

The committee of the New England Water-works Association deserve much credit for originating the idea which has resulted in this collection, and also for the work done in securing the sketches and preparing them for publication. How great the labor required to make such a collection is, only those who have undertaken similar work can appreciate. The *Engineering and Building Record* has brought out the volume in excellent form. We are promised a continuation of this work hereafter, the committee having already three additional sketches contributed toward another volume.

Mineral Resources of the United States, 1886: by David T. Day, Chief of the Division of Mining Statistics and Technology, United States Geological Survey. Washington; Government Printing Office.

This volume is the fourth of the series begun in 1882, which was intended to give year by year a comprehensive view of the mining and mineral industries and resources of the United States. How extensive these are may be gathered from the summary given in the report, which places the value of the metallic products for 1886 at $215,364,825, and of the non-metallic mineral products (including coal, ores of all kinds, stone, etc.) at $243,963,063; a total of $459,327,888.

The general summary and statement is followed by a number of papers on various mining and mineral industries. These papers are for the most part by specialists in the several departments. Iron, coal, and coke are naturally given leading places, but much space is also taken up by interesting articles on copper, on lead, and on structural materials. A monograph on natural gas is furnished by Mr. J. D. Weeks, of Pittsburgh. A valuable supplement continues the summary of mining law begun in a previous year, especial attention being given in this volume to the laws of the States east of the Mississippi.

The previous volumes of the series (1882–85) have shown generally a decrease in values and either decreases or but slight gains in production. The year 1886 showed a notable increase both in production and in values of mineral products. A large part of the total gain was due to the increase in both production and prices of iron and steel, which was so remarkable a feature of the year.

BOOKS RECEIVED.

The Iron Age, for so long an authority in the hardware and metal trades, makes a new departure with the new year and changes from its old "blanket sheet" form to a page only a little larger than that of the Journal. The change is a very great improvement, making the paper of a convenient size to read and handle, and showing to much better advantage the fine typographical work which has always been a feature with it. The *Iron Age* has done much to deserve its present prosperity, and promises still better for the future.

The Locomotive Engineer is a new monthly paper issued by the American Machinist Company, and is intended especially for the benefit of locomotive engineers and firemen. It is edited by Mr. J. J. Hill, who was until recently an engineer on the Denver & Rio Grande Railroad. The first number of the new paper makes an excellent appearance; it is, apparently, inclined rather toward the practical than the theoretical.

Tables for Calculating the Cubic Contents of Excavations and Embankments; Volume II: by John R. Hudson, M. Am. Soc. C. E. New York; John Wiley

& Sons. This is the second volume of Hudson's well-known *Tables*. While it is a continuation of Volume I, it is so arranged that each volume is independent of the other and complete in itself. In the present volume the author gives several methods of computing earthwork quantities entirely different from those of the first.

A TEXT-BOOK ON ROOFS AND BRIDGES: PART I; STRESSES IN SIMPLE TRUSSES: BY MANSFIELD MERRIMAN, PROFESSOR OF CIVIL ENGINEERING IN THE LEHIGH UNIVERSITY. New York; John Wiley & Sons. (Price, $2.50.)

FIFTEENTH ANNUAL REPORT OF THE COMMISSIONER OF RAILROADS OF THE STATE OF MICHIGAN, FOR THE YEAR 1887: JOHN T. RICH, COMMISSIONER. Lansing, Mich.; State Printers. This report contains some unusually interesting statements; some extracts are given on another page.

FIFTH ANNUAL REPORT OF THE BOARD OF RAILROAD COMMISSIONERS OF THE STATE OF NEW YORK, FOR THE YEAR ENDING SEPTEMBER 30, 1887: WILLIAM E. ROGERS, ISAAC V. BAKER, JR., MICHAEL RICKARD, COMMISSIONERS. Albany, N. Y.; State Printers.

THE TAYLOR IRON WORKS: DIARY FOR 1888. New York; issued by the Company. The Taylor Iron Works have for a number of years issued a very convenient diary in pocketbook form, which, in addition to the usual calendars, pages for memoranda, etc., contains some 30 pages of condensed information very convenient for an engineer to have with him for reference. The diary for 1888 is in the usual form.

OUR MERCHANT MARINE: ITS CONDITION AS SHOWN BY THE ADMINISTRATION AND THE ADMIRAL OF THE NAVY: 1888. Issued by the American Shipping & Industrial League.

THE ELASTICITY AND RESISTANCE OF THE MATERIALS OF ENGINEERING: BY WILLIAM H. BURR, C. E. New York; John Wiley & Sons.

AMERICAN BRAKE COMPANY: ILLUSTRATED CATALOGUE OF LOCOMOTIVE BRAKES. St. Louis; issued by the Company.

THE FOWLER STEEL CAR WHEEL: CATALOGUE AND DESCRIPTION. Chicago, Ill.; issued by the Fowler Steel Car Wheel Company.

Contributions.

THE MECHANICAL EQUIVALENT OF HEAT.

BY PROFESSOR DE VOLSON WOOD.

IT is now more than 40 years since the work which is the equivalent of a given amount of heat was determined by Joule of England. The results of those experiments were by no means uniform, but Joule, after a long series of experiments, and a patient and laborious discussion of the results, in which he seemed to give more weight to the smaller than to the larger values, finally concluded that the heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit above the melting point of ice was equivalent to 772 foot-pounds of work. This value has been universally adopted by the scientific world, although more recently it has been admitted that that number is too small.

In 1876 a committee of the British Association for the Advancement of Science reported to that body that the mean 60 of the best of Joule's experiments gave 774.1 foot-pounds, but this number has not yet been used, at least to any extent.

Still more recently, about 1880, Professor Rowland made a critical examination of the specific heat of water from about 40° F. to above 90° F., determining the value for each degree and the corresponding value of the mechanical equivalent.

The investigation included the comparison of the air thermometer with the best mercurial thermometer, and a comparison of the mercurial thermometers used with the one used by Joule. The results of these experiments were published in the proceedings of the American Academy of Arts and Science, 1880. It is observed that when Joule's experiments are reduced to Rowland's thermometer and for the latitude of Baltimore, they agree almost exactly with those of the latter, the latter being about $\frac{1}{1000}$ of the mechanical equivalent larger.

But the interesting and unexpected discovery was made that the specific heat of water was greater at 40° than at 80°, and that it appeared to be a minimum near the latter point. This was contrary to the law given by Regnault's experiments, for, according to the latter, the specific heat of water increases from the melting point of ice as the temperature increases, and as this law was used by Joule in reducing the equivalent from 60°, the temperature near which his experiments were made, to its value at the temperature of ice-cold water, the resultant value would be somewhat less than the value found by direct experiment. The same remark applies to the value given by the committee of the British Association; hence, not only is 772 too small, but 774.1 is also too small.

There are physical reasons for not using the melting point of ice from which to measure the degree of rise of temperature. It is a critical point, and the water at that point may be absorbing heat preparatory to a change of state of aggregation. The condition of maximum density is a much more desirable point of reference. Water under the pressure of one atmosphere has a maximum density at 4° Centigrade, or 39.2° F. Omitting decimals, Rowland's investigations gave 778 as the mechanical equivalent of heat at 39.2° F., according to the mercurial thermometer, and 783 according to the air thermometer. In my recent work on thermodynamics I have used 778, not merely because that was one of the values found by Rowland, but because it agrees fairly well with the result found by other means, and also because we may, when using that number, consider the specific heat of water as constant without much error; whereas if 783 were used, the variable specific heat ought to be taken into account. We also notice that Rowland found 778.4 for the equivalent at the latitude of Baltimore for the air thermometer when the temperature of the water was 60.8° F.

We are confident that the old number, 772, will sooner or later be abandoned and a larger value used, because nearer correct; but it remains to be seen whether 778 will be adopted. It is apparent that for accurate scientific work the value used should be one determined in reference to the air thermometer, and for a particular degree of the scale, and all departures from uniformity—such as a variable specific heat—be determined.

THE PRINCIPLES OF RAILROAD LOCATION.

By Professor C. D. Jameson.

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(*Continued from page 14.*)

CHAPTER VIII.

VERNIERS.

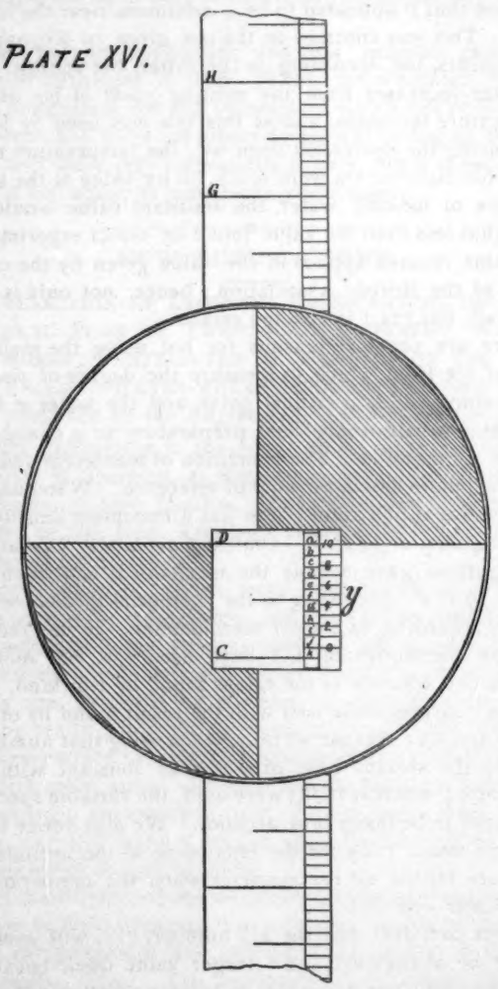
The Vernier has been referred to in several of the descriptions of instruments used in location. Its use is so general that a special description is given below.

A vernier is a contrivance by means of which smaller divisions of distance are read than the actual divisions made on the scale or rule. By its use exceedingly small divisions can be read by the naked eye.

On railroad work the vernier is used upon a level rod in taking turning-points and upon the transit in measuring angles.

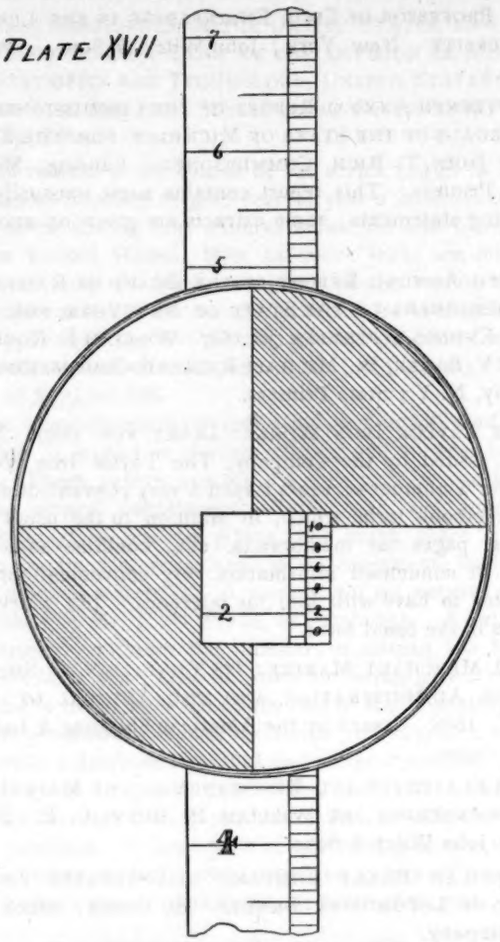
The principle of the vernier is as follows: Take any scale, as Plate XVI, which represents a part of the level rod. The large divisions *A*, *B*, *C*, *D*, etc., are tenths of feet. These tenths of feet are divided each into 10 parts, making .01 of a foot. Now, it is desired to measure distance to the thousandth of a foot. If the smaller divisions, or .01 ft., are to be divided into 10 parts, making .001 ft., each of these divisions would be so small as to be scarcely perceptible to the naked eye, and this subdivision, owing to the increased amount of work on the rod, would also increase the cost very much. Now, the object of the vernier is to permit the reading of .001 ft. without the necessity of dividing each hundredth of a foot into 10 equal parts. The way in which it is accomplished is as follows:

Plate XVI.



The rod is divided into hundredths of a foot, *a*, *b*, *c*, etc., then the vernier scale *y* is made equal in length to nine of these small divisions *a*, *b*, *c*, and is divided into 10 equal parts. Then 10 equal parts of a vernier scale are one-tenth shorter than 10 equal parts of a rod scale, and, consequently, each small division of the vernier is one-tenth shorter than each small division of the rod—that is, the difference between the divisions on the vernier and those on the rod is .001 ft.

Plate XVII



Numbering the divisions on the vernier scale from zero to 10, as shown in Plate XVI, then the number 10 on the vernier scale comes opposite the ninth division on the original scale, and if the rod be slipped down until No. 1 on the vernier scale corresponds with No. 1 on the original scale, then the rod has been moved .001 ft. In like manner, if the rod is moved so that No. 6 on the vernier scale corresponds with No. 5 on the original scale, it has been moved .006 ft. Thus it is very easy to read with the naked eye down to .001 ft., and with much more exactness than if the original scale had been actually divided into thousandths of feet.

The vernier was invented in 1861, and takes its name from the name of the inventor.

Plate XVIII represents the two plates of a transit, the vernier scales *A* and *B* diametrically opposite each other. These verniers can be divided in a number of ways, and

the most common way is as follows: The outside circle is divided into degrees and half degrees. Take 30 of these smallest divisions on the outside circle and make the vernier equal 29 of them, and divide it into 30 parts; we are thus able to read to minutes in angular measure.

PLATE XVIII

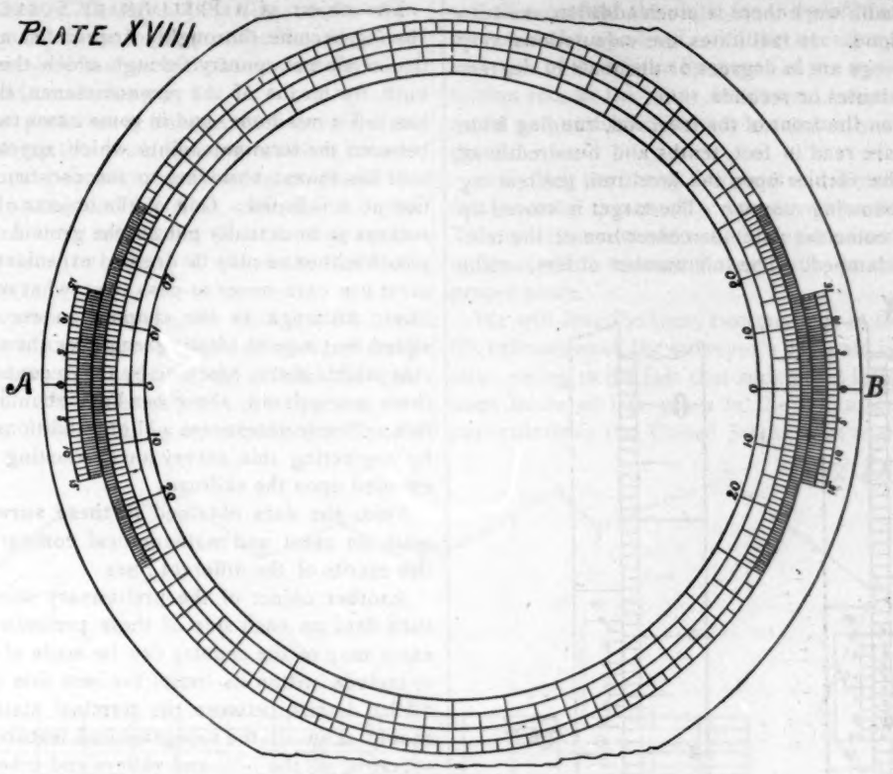
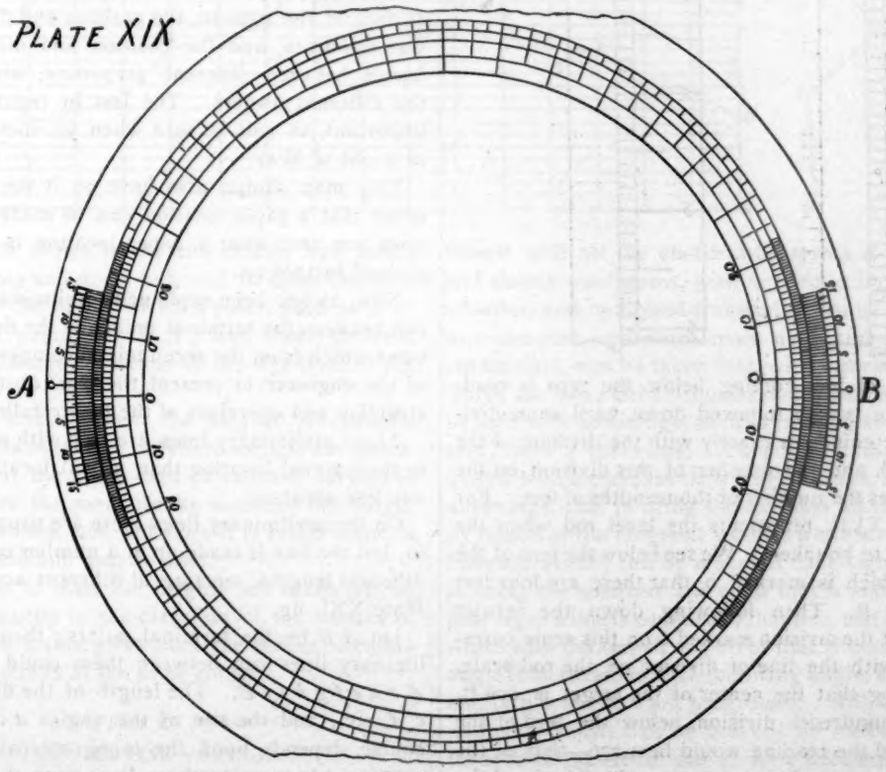


PLATE XIX



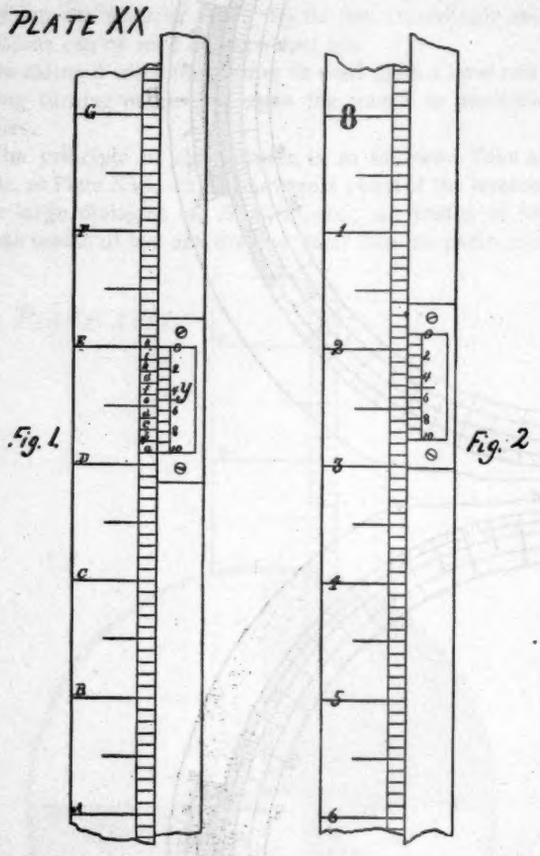
Where more exactness is required the circle is divided into degrees and thirds of a degree (20 minutes). Then 20 spaces on the vernier are equal to 19 spaces on the circle, which reads to minutes, or if it is required to read the half minutes or 30 seconds, then 40 spaces on the vernier are made equal to 39 spaces on the circle. In the same manner the most minute divisions of angular measurement can be read. Of course the only limit to this is the length of the diameter of the circle, because as the divisions become finer and finer, on an ordinary transit they become too fine for accuracy and increase the cost, so that they seldom read to less than 30 seconds.

The transit, when it is to be used for stadia measurements, frequently has a vernier divided on the decimal system, so that any reading of angular measurements is taken in de-

grees or decimals of degrees. The advantage of this, in the case of stadia measurements, is that under ordinary circumstances all the angular measurements are taken from the azimuth to the right, the same as the hands of a watch, through the whole 360 degrees of the circle, and in notes taken in stadia work there is much addition and subtraction to be done. It facilitates the calculations very much if the readings are in degrees or decimals of degrees rather than in minutes or seconds.

The numbers on the front of the level rod, running from the bottom up, are read in feet, tenths and hundredths of feet. In using the vernier upon the level rod, the reading is taken in the following manner: The target is moved up or down until it coincides with the center line of the telescope and then clamped. The full number of feet, tenths

PLATE XX



and hundredths of feet coming below the zero is read. The vernier scale is then followed down until some division on the scale coincides exactly with the division of the scale on the rod, and the number of this division on the vernier scale gives the number of thousandths of feet. For example: Plate XVII represents the level rod when the reading is about to be taken. We see below the zero of the vernier scale, which is marked 0, that there are four feet with .2 and .07 ft. Then following down the vernier scale we see that the division marked 6 on this scale corresponds exactly with the line of division on the rod scale, therefore showing that the center of the target is .006 ft. above the last hundredth division, below the zero of the vernier scale, and the reading would be 4.276—that is, the center of the target is that distance from the bottom of the rod.

Plate XX represents the vernier on the side of the level rod. The numbering on the rod reads from the top down, as the back of the rod is pushed up, the vernier remaining stationary on the front part of the rod, as shown in fig. 2, where the reading is 8.186.

CHAPTER IX.

PRELIMINARY SURVEYS—PURPOSES.

The object of a PRELIMINARY SURVEY is as follows: Having become thoroughly acquainted and familiar with that section of country through which the railroad is to be built, by means of the reconnoissance, the engineer then has in his mind one, and in some cases two or more, lines between the terminal points which appear to him to present the fewest obstacles to the construction and operation of a railroad. One of the objects of the preliminary surveys is to actually put on the ground as many of these possible lines as may be deemed expedient. The engineer must use care never to pass over what might be the best line. Although in the chapter on reconnoissance it is stated that a good locating engineer should be able to decide which is the best line by the reconnoissance, still, if there is any doubt, the other lines should be surveyed, as this will only necessitate a slight additional expense, while by neglecting this survey an everlasting expense may be entailed upon the railroad.

From the data obtained by these surveys there can be made an exact and mathematical comparison of the relative merits of the different lines.

Another object of the preliminary surveys is to obtain such data on each side of these preliminary lines that an exact map of the country can be made of such a width as to include within its limits the best line for a railroad, in all its details, between the terminal stations. This map should show all the topographical features of the country—that is, all the hills and valleys and other changes in the surface of the ground, the position and direction of all the water-courses, and the position and direction of all the fences between different properties, with the names of the different owners. The last in regard to property is important, as will be seen when we come to the question of Right of Way.

This map should also have on it the contour lines, in order that a paper location can be made. What contour lines are and what a paper location is will be fully explained further on.

Now, as has been explained, preliminary lines are lines run between the terminal points in the field in those positions which from the reconnoissance appeared in the mind of the engineer to present the least obstacles to the construction and operation of the future railroad.

These preliminary lines are run with much less care as to their actual location than a final location, but not with any less accuracy.

On the preliminary lines there are usually no curves put in, but the line is made up of a number of straight lines of different lengths, meeting at different angles, as shown in Plate XXI, fig. 1.

Let *A B* be the terminal points; then one of the preliminary lines run between them could take the form of *A c d e f g h i j B*. The length of the different lines *A c*, *c d*, etc., and the size of the angles *a c d*, *c d e*, etc., of course depends upon the topographical features of the country. In running these lines upon the ground enough data must be taken to enable the engineer to make accurate plans and profiles of each line. By the plan of a railroad line (Plate XXI, fig. 1) or a section of country we mean that we show on paper exactly what we would see if

we were above that section of country and looking down upon it—that is, we see the horizontal length and direction of every feature on it, but we do not see any vertical changes—that is, we do not see any of the ups or downs of its surface.

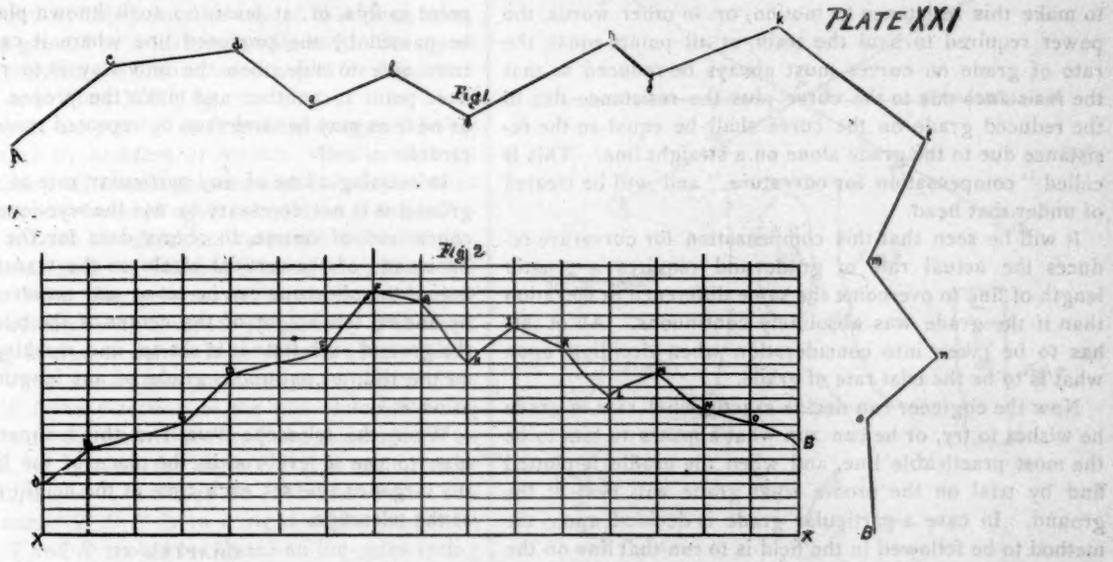
In the profile (Plate XXI, fig. 2) of a line, on the contrary, we are supposed to be looking at the line from one side, so that we see only the vertical changes of direction and none of the horizontal changes.

In order to plot a preliminary line we must know the exact length of each of the short lines of which it is composed, and these can be measured either by means of the measuring chain or the stadia. Also, each of the angles at which these short lines meet must be accurately measured, and this is done by means of either the transit or surveyors' compass.

In making the profile of a line, the data that we need are the height above some known point or plane of every point in the line where the surface of the ground changes, and also the horizontal distance between these points.

We will suppose Plate XXI, fig. 2, to be the profile of a

PLATE XXI



line *A B*—that is, it shows where and exactly how much the line *A B* runs up and down-hill, and to make this profile we must know the height of each point, such as *B C*, above some fixed point, like *X X*; and these different heights are found either by means of the wye-level or the stadia.

When the wye-level is used, the heights are usually taken at every chain or station. Where feet are the standard of measurement the chain used on railroad surveys is 100 ft. long; where the meter is the standard the length of the chain used varies, but, although it is rather short, a 20-meter chain is the one usually used.

When the stadia is used the heights are taken only at each important change in the direction of the surface of the ground, as the stadia gives both the vertical heights and horizontal distances at the same time.

CHAPTER X.

PRELIMINARY SURVEYS—METHODS.

Having thus fully explained what data must be obtained on a preliminary survey, and having described and explained the various instruments used, we will now show the methods used in the field by means of which the required data are obtained with the instruments used.

The methods used in the field on preliminary surveys may be divided into two classes:

1. The one which until very recently has been in general use—that is, running as many lines as may be deemed necessary by means of the surveyor's compass or transit, and then getting the data for the profile of these lines by means of the wye-level, with the necessary topography on each side of the selines by means of the wye-level, the cross-section rod, or the slope instrument, when both the horizontal and vertical distances are actually measured on the ground.

2. Getting horizontal distances and direction and vertical distances by means of a transit with stadia attachment. This is the more modern method, the advantages of which, under certain circumstances, will be explained in the proper place.

We will describe these two methods in the order named. On railroad work the surveyor's compass is very little used now, owing to the fact that such great improvements have been made of late years in the manufacture of transits, particularly in the United States, that to-day the railroad transit with all the stadia attachments is a light, strong, and simple instrument, with very little liability to get out of order, and by a good transitman can be used as quickly as a compass, and much more data, and much more accurate data, can be taken than with a surveyor's compass. There are some circumstances under which a compass can be used with advantage, such as running side lines or "offsets" from a main line. A smaller number of men is required with a compass than with a transit, and there is this advantage, that in using the compass all the lines are run by means of the magnetic needle, while with the transit all lines are usually run by means of back-sights. Therefore, in using the compass any error that is made in taking the bearing of a line is confined to that line, and goes no further; while with the transit any error that is made in reading an angle is increased in each following angle, and grows larger and larger as the work progresses. Still, as every line run with the transit can be checked by means of the needle, there is no excuse for one of these accumulative errors.

Before running a trial or preliminary line through a country, the engineer should decide within certain limits what the rate of grade is going to be.

From the data which have been obtained on the reconnoissance there should be very little difficulty in doing this.

For instance, if the line is to run up a valley, and in order to cross the range is obliged to run through a certain pass, we know from the reconnoissance the height of this pass as compared with some point at the foot of the hills where the line can begin to climb, and we also know approximately the distance between these points. We can, therefore, with the difference in elevation and the distance between them, get the rate of grade of any straight line drawn between the two points. But as any line upon which it would be practicable to build a railroad would in hardly any case be a straight line, it would be longer, and therefore the rate of grade to reach the same elevation would be less. There is, however, another point to be considered here. We will make only mention of it now, as it will be fully discussed later. This point is, that in any continuous grade or any grade where it is desired to use the same amount of power to haul the same train up the entire length, there must be a "let up" in the grade on every curve. There is a certain amount of resistance to moving a train due to a grade, and also a certain amount due to each degree of curvature, so that in order to make this resistance to motion, or, in other words, the power required to haul the train, at all points equal, the rate of grade on curves must always be reduced so that the resistance due to the curve plus the resistance due to the reduced grade on the curve shall be equal to the resistance due to the grade alone on a straight line. This is called "compensation for curvature," and will be treated of under that head.

It will be seen that this compensation for curvature reduces the actual rate of grade and requires a greater length of line to overcome the same difference in elevation than if the grade was absolutely continuous. All of this has to be taken into consideration when deciding upon what is to be the trial rate of grade.

Now the engineer can decide exactly what rate of grade he wishes to try, or he can run what appears to him to be the most practicable line, and when the profile is plotted find by trial on the profile what grade will best fit the ground. In case a particular grade is decided upon, the method to be followed in the field is to run that line on the ground which will give approximately the required rate of grade without any cuts or fills. In a rough country this line will, of necessity, be an extremely crooked one. When this line has been run and plotted on paper, then a line with suitable curves is plotted over it, and the more nearly this second line corresponds to the first, or grade line, the less work there will be on construction.

In running this grade line on the ground, when a ravine or other obstacle is encountered which it is obvious would take too great a length of line, or as it is called, "development," to run around, then the line is at once located over or under it. In the same manner, when any of the obstructions met with are of such a slight nature that practically they offer no impediment to the construction of the road, the line is simply run over them.

Whenever a line is, from the topographical formation of the country, obliged to pass a certain point in a range of hills or mountains, the engineer should always commence the line at the pass, and run backward, if necessary, to the more open lower country.

The advantage of this is, that the point where the line must cross the summit at the pass is fixed, and cannot be changed, and also the rate of grade is within certain limits, if not absolutely, fixed, while the point where the line leaves the open country and begins to climb is not absolutely fixed, and within certain limits can be shifted from one side to the other as the exigencies of the rough country beyond require.

By commencing at the pass with the depth of cut that has been decided upon, and then dropping down with the required grade, we obtain at once the two elements that are fixed, and leave to the topographical formation of the country only the third element (that is, the point where we enter or leave the lower land), and which can be varied. On the other hand, if we start at a fixed point at the foot of the hills and run up on a fixed grade, we may have to run any number of lines before we hit the pass at the required elevation, either by not developing enough or too much, as the case may be.

Under many circumstances, however, each end of the line is absolutely fixed. In this case, two lines can be started, one from each end, and run until they intersect or until some point is reached where they can be shifted from side to side without great detriment to the cost of construction, and thus joined. In case there is no such point as this, or, at least, no such known place, that can be passed by the proposed line where it can be shifted from side to side, then the only way is to run from one fixed point to another and make the proper development as near as may be, and then by repeated trials correct any errors.

In running a line of any particular rate of grade on the ground it is not necessary to use the wye-level except as a check and, of course, to obtain data for the profile; but by means of the vertical circle on the transit the center line of the telescope can be set at any required angle, and by finding the height of the center of the telescope above the ground each time it is set up, and marking this height on the rod, a continuous grade of any length may be run at once.

When the telescope is used in this manner it is a good plan to use a level-rod in the place of the lining rod, as the target can be set each time at the height of the center of the telescope.

CHAPTER XI.

THE SURVEYING PARTY.

The party on a preliminary survey is as follows:

Chief of party	1	
Transitman	1	
Chainmen	2	
Rodmen	2	
Stakemen	2	
Axemen	2	= 9
Leveler	1	
Rodman	1	= 2
Topographer	1	
Assistants	2	= 3
Cook	1	
Teamsters	2	= 3
Total		18

The duties and methods of work of each are as follows:

The entire party is under the direction of the Chief of Party, who is held responsible for the amount and class of work which is done, and who reports directly to the Chief

Engineer or Chief Assistant. This Chief of Party has not only to see that the work progresses with all possible speed and accuracy, but also has many other duties. He must see that his party is properly lodged and fed, and, above all, that perfect discipline is maintained; that each member of the party not only understands what his duties are, but that every night all these duties required have been performed and none of to-day's work left for to-morrow.

The Chief of Party has received full instructions from the Chief Engineer as to the lines that are to be run and the methods to be used in the field. He is well acquainted with the country, and has the best procurable maps of it. Before starting any work in the field he must have a clear and comprehensive idea of what he has to do and exactly how it is to be done. The Chief of Party knowing all this, the work commences and proceeds as follows:

The Chief of Party shows the Transitman the point from which the line is to start. If this point is not already well defined it must be made so before the work proceeds. The most common way is to drive a short stake called a "plug" (about 4 in. long and 1½ in. in diameter) firmly into the ground at the point, the top of this plug being even with the ground or a little below it, and in the top of this plug directly on the transit point a tack or small nail is driven in, as in Plate XXII, fig. 2.

In this manner the point is in very little danger of being disturbed either by accident or malice. But in addition to this precaution all transit points which it is desirable to save, or which may be used again, should be "tied in"—that is, they should be referenced to points on some permanent objects, such as buildings, trees, etc., in such a manner that if the plug gets moved in any way the point can be re-established with accuracy and speed. The usual way of tying in transit points is as follows (Plate XXII, fig. 1): Let *P* be the transit point which it is desired to tie in, and *P L* the direction of the line which is being run. Then with the transit at *P* and the telescope set on the line *P L*, we turn off the angle *T P L* to some tree or permanent object as *T*, and then on another tree *R*. The nearer the angle *T P R* is to a right angle the better. These trees *T* and *R* should be blazed on the sides facing *P* and a tack point made, as shown in Plate XXII, fig. 3, where *A* is the tack point driven into the blaze and *B* is a circle round the tack point made with keel or whatever the stakes are marked with. While the telescope is sighted on the tack points in the trees the plugs *s s* are driven about half way between the trees and the transit, or the telescope is reversed and the plugs *d d* put in the other side of the transit. The points where these plugs will be driven will, of course, depend upon the topography of the place. These plugs have tack points put in the top, and the distances from the trees to their respective plugs are measured and noted in the transit book. Then in case the point *P* becomes lost, the transit is set up on one of the plugs and the telescope sighted on to the tack point in the tree *T*. Then in this line two plugs, *x* and *y*, are driven with tack points, one on each side of where the original point *P* was. The transit is then set up over the other plug *d* or *s* and sighted on the tack point in the tree *R*.

A small cord is stretched from *x* to *y*, and then the lining rod is moved along this cord until it is in line with *d R*, when a plug is driven, and the tack point on this plug, being exactly at the intersection of the two lines *d T* and *d R*, is the original point *P* wished for.

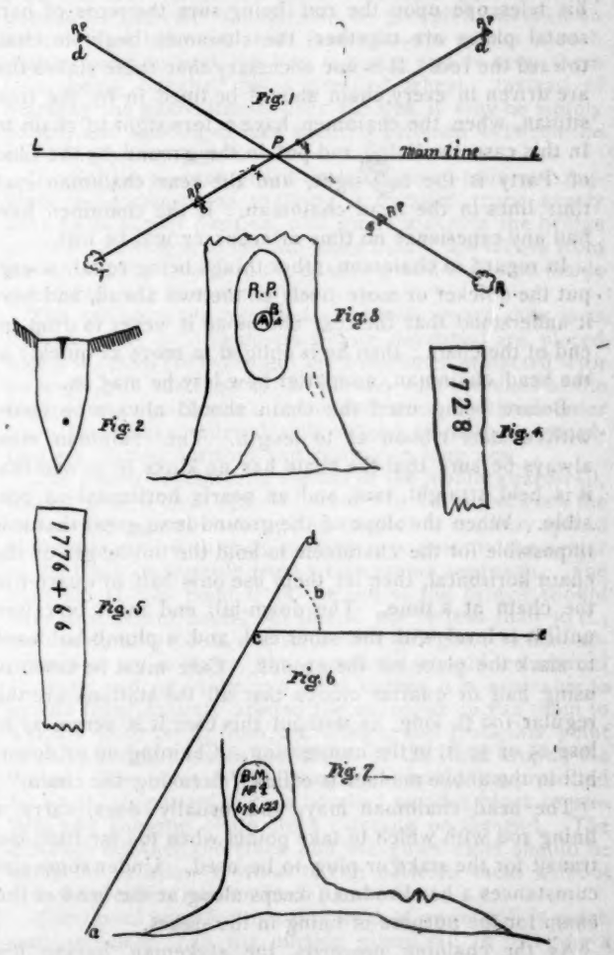
The trees *T* and *R* should be far enough from the main line to give sufficient height of line for a back-sight, and also to be outside the line of clearing the right of way.

This tying in and preservation of transit points applies not only to the starting-point, but to all transit points on the line that would be needed if it should become necessary to retrace the line at any time. At one side of the plugs *s s* or *d d* and 2 ft. from them should be driven stakes marked *R P*. The side of the stakes on which the letters are should face the plugs.

Every transit point that is put in should be guarded in the same way by a stake properly marked at one side. If the line starts from a line of railroad already built, care must be taken to make sufficient measurements to any switches, buildings, culverts, or any other permanent objects which will enable the draftsman to connect the new line to the plans of the old line without any trouble.

In running through towns care must be taken to desig-

PLATE XXII



nate exactly all street crossings, with all necessary angles and measurements.

In running preliminary lines, stakes should be put in every chain and numbered. The usual way is to call the starting-point 0 and then number 1, 2, 3, etc.

This is the manner when the 100-ft. chain is used. When the 20-meter chain is used the starting-point is 0, and then each 20 meters is called two stations, so that the numbers run 0, 2, 4, 6, etc., a station being 10 meters long and stakes being put in only at every other station.

The stakes should be about 2 ft. long and driven straight and firmly in the ground. The side of the stake that has

the number on it should always be turned toward the preceding stake, so that any one in walking over the line in the direction in which it was run will be able to read the numbers. This, of course, does not apply to the guard stakes at the transit points, the positions of which have already been described.

The stakes should be numbered as follows (Plate XXII, fig. 4): The number beginning at the top of the stake and running toward the point. One side of the stake should be smoothed, so that the number can be written on it clearly. The usual material for marking stakes is keel, for the reason that rain does not wash the mark off.

When the starting-point has been decided upon and marked either by means of a plug or in some other way, the transit is set over it. While this is being done the Chief of Party goes ahead with a lining rod, and by means of this rod, which he sticks into the ground at any desired point, indicates to the transitman the direction in which the line is to be run. As soon as the transitman has set his telescope upon the rod (being sure the zeros of horizontal plates are together) the chainmen begin to chain toward the rod. It is not necessary that these stakes that are driven in every chain should be lined in by the transitman, when the chainmen have a fore-sight to chain to. In this case the lining rod put in the ground by the Chief of Party is the fore-sight, and the rear chainman each time lines in the head chainman. If the chainmen have had any experience no time or accuracy will be lost.

In regard to chainmen, other things being equal, always put the quicker or more lively of the two ahead, and have it understood that the rear chainman is never to drop his end of the chain; then he is obliged to move as quickly as the head chainman, no matter how lazy he may be.

Before being used the chain should always be tested with a steel ribbon as to length. The chainman must always be sure that the chain has no kinks in it, and that it is held straight, taut, and as nearly horizontal as possible. When the slope of the ground is so great that it is impossible for the chainmen to hold the full length of the chain horizontal, then let them use only half or quarter of the chain at a time. The down-hill end must be raised until it is level with the other end, and a plumb-bob used to mark the place on the ground. Care must be taken in using half or quarter chains that all the stations are the regular 100 ft. long, as without this care it is very easy to lose 25 or 50 ft. in the numeration. Chaining up or down-hill in the above manner is called "breaking the chain."

The head chainman may, and usually does, carry a lining rod with which to take points when too far from the transit for the stake or plug to be used. Under some circumstances a head rodman keeps along at the head of the chain for the purpose of lining in the stakes.

As the chaining proceeds, the stakeman having his stakes properly numbered and ready, drives them, as before directed, at every chain. When the point that the Chief of Party indicated has been reached, a plug is put in with tack point and guard stake. On this stake should be noted the number of the station if the plug comes at a full station; if not at a full station, the stake should be marked with the number of the preceding station plus the distance from this station to the plug, as shown in Plate XXII, fig. 5. Then Station 1777 would be 34 ft. from the transit point in whatever direction the line runs.

The object of thus numbering the stakes is that all the stations may be of equal length, so that whatever number is on a stake will indicate the distance of that stake from o.

The transitman takes the magnetic bearing of the line and notes it in his transit book. He then takes his transit and moves on to his first transit point, the Chief of Party in the meantime having gone ahead to indicate the direction of the new line. The rear rodman stops at the point just left by the transitman.

When the transit is set up on the new point the first care after leveling the instrument is to see that the zeros of the horizontal plates are together; then set the vertical cross-hair on the rear rod, which should be held vertically by the rodman on the last point as a back-sight until the transitman signals "All right."

In sighting upon a rod the transitman should always sight as near the foot of the rod as possible, as in this way he is more sure to near the actual point than in sighting at the top of the rod in case the rodman holds the rod out of plumb. In holding a lining rod the rodman should stand directly behind it with his feet apart, and hold the rod lightly with both hands. The lower end of the rod, being shod with metal, will by its own weight bring the rod vertical if held so lightly that it is free to swing a little.

The principal duty of the rear rodman is to so watch the transitman for signals that no time may ever be lost in vain endeavors to attract his (the rear rodman's) attention. When the telescope is set on the back-sight it is reversed, and the transitman is prepared to start in any direction with his line.

When the new direction has been given him he unclamps only the upper plate and sets his telescope on the new fore-sight, and then from the horizontal plates he reads off the number of degrees of the angle between the two lines, as shown in Plate XXII, fig. 6. In this let *a d* be the first line and *c e* the second line, then the angle that is measured is *d c e*. The magnetic bearing of the second line should also be taken. In taking these bearings the reading of the needle is not as accurate as the reading of the degrees and minutes of the angles of intersection, but they serve as a check on the measurements of the angles, and make any large error impossible.

The number of axemen and stakemen needed depends on the character of the country through which the line runs. In an open country, where long sights are possible and little or no clearing is to be done, two or more stakemen may be needed, and only one axeman, while in a rough, wooded country the reverse may be the case in regard to both axemen and stakemen, as fewer stakemen are required when the progress is slow.

The duties of the axemen are to clear away any obstacle that may obstruct the view of the transitman, such as brush, trees, branches, etc. Care should be taken to make the path cleared as narrow as possible, and at the same time to make the clearing thorough, so that the axemen need not be called back to do any work a second time. In axemen experience is of great advantage, both as to cutting on a line and making the cut thorough the first time. On preliminary lines too much time should not be lost in cutting down large trees. The line should be shifted to one side or the other for any tree over 6 in. in diameter, or else a new line started. The object is not to lose any time.

In a rough, wooded country it often happens that the Chief of Party is unable to see the transitman when he wishes to give a new direction. In this case the direction

is given by shouting. With some care and practice a transitman can follow very closely the sound of a voice.

All members of an engineering party should have a perfect understanding as to a code of signals by either the arms or flags, by means of which they may to a greater or less extent communicate with each other when too far apart to be able to make themselves heard when speaking. There should always be as little shouting and noise as possible. It delays the work and shows great ignorance on the part of the workers.

When several lines are run between the same terminal points they should be distinguished one from the other both in the notes and on the stakes in the field thus: *A* or *B* or *C*.

Very often during a preliminary survey part of a line may be changed, and as it would be a great loss of time to change the whole numbering of the line, the method used is then as follows: Let the first line be *A B*, 900 ft. long and approximately straight. Then we will suppose that between stations 3 and 8 there is a spur of a hill which it is advisable to run around on the line 4′, 5′, 6′, etc., until it rejoins the original line at station 8. The numbering of the stakes is continued on the new line the same as on the original line up to station 7′. Then as station 8 is in the original line and we wish the numbering to continue the same in that line, we make in this case what is called a "long station"—that is, we measure the distance from station 7′ of the new line to 8 of the old line and call it one station. In this case this would be 180 ft., and a note must be made in the note-book that station 7′ is 180 ft. long. In case the new line had been shorter than the old line, then the last station would have been a "short station," and must be so noted in the note-book, with its actual length.

When a new line starts from an old line and runs in any direction so as to become in itself a line and not a mere change in the original line, then it has a numeration of its own, and in the notes the points where this line meets or crosses any other line must be noted as follows:

Station 10 + 40 line *A* = to
Station 0 line *B*. Or
Station 123 line *A* = to
Station 23 + 4 line *C*, etc.

Whenever the surveyor's compass is used for running lines, the manner of proceeding is about the same as has been described for the transit, with the exception that no back-sights are taken, as the direction of all the lines is taken by the magnetic needle, and not by direct angular measurement. The use of this instrument, as has been said, is now, on railroad work, confined principally to the running of cross-section lines—that is, lines run at more or less of an angle with the main line for the purpose of obtaining topographical data.

The Chief of Party should give especial attention to the determination of the length of the bridges that may be necessary, and the openings of culverts. He should keep a note-book containing all this data, also all the data he can collect in reference to the drainage of the area that is passed over, the cross-section of the streams when at their highest, and all the general information possible. These notes should be made as clear, full, and explicit as possible, containing all the local names of streams, rivers, etc., and all of these should be referenced to the nearest stake in the line of the survey.

Every night the transitman must plot all the work done by him during the day. This plot should then be carefully examined by the Chief of Party to see if any changes are to be made or if the work is to proceed.

(TO BE CONTINUED.)

Guard-Rails on Bridges.

THE Massachusetts Railroad Commission has recently issued a circular to the railroad companies of the State on safety at railroad bridges. This circular speaks of guard-rails and guard-timbers as follows:

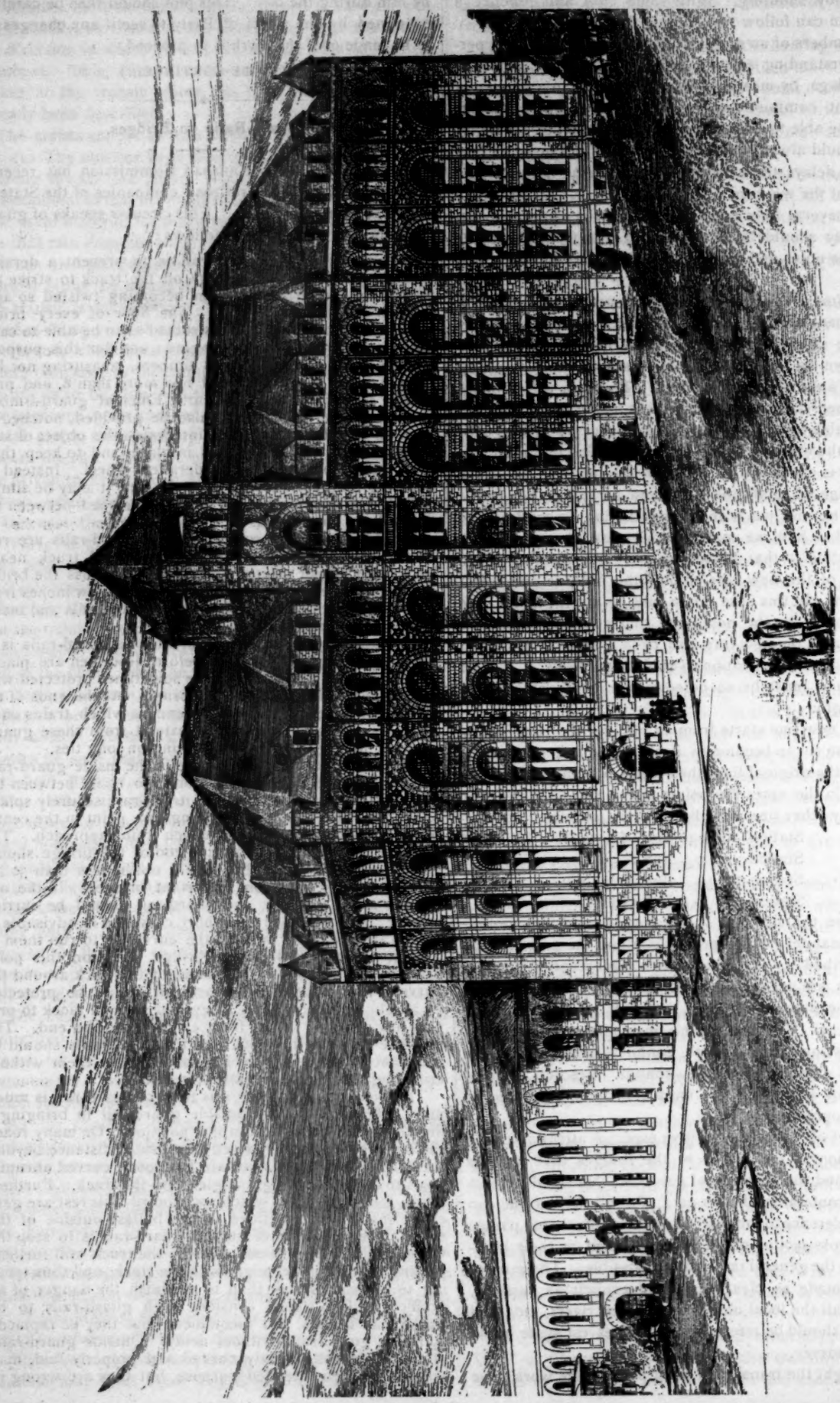
The object of the guard-rail is to prevent a derailed truck from getting far enough off the track to strike any portion of the girder, or from becoming twisted so as to lead to further derailment. The floor of every bridge should, moreover, be so constructed as to be able to carry safely any derailed car or engine; and for this purpose, the ties should be substantial timbers, measuring not less than 6 by 8 in., and spaced not more than 8, and preferably 4 or 6 in. in the clear. Efficient guard-timbers outside of the rails should also be provided, notched on each tie and bolted at short intervals—the object of such timber being to hold the ties in place, and to keep them from being bunched by a derailed wheel. Instead of notching the guard-timber over the ties, it may be simply bolted, and spacing-blocks securely fastened between the ties to keep them apart.

In addition to such guard-timbers, guard-rails are requisite, so arranged as to bring a derailed truck nearly back to its proper position, and guide it across the bridge without allowing it to deviate more than a few inches from the rails. For this purpose, outside guard-rails and inside guard-rails are in common use.

The ordinary arrangement of outside guard-rails is as follows: The guard-timbers before described are placed 6 or 8 in. from the rails, and are sometimes protected with an angle-iron fastened to the corner. At the ends of the bridge, or on each track at the end at which trains enter upon the bridge, curved rails extend from these guard-timbers, flaring outward and resting on long ties.

The Board recommend the use of the inside guard-rail, placed with a clear space of from 7 to 10 in. between the heads of the guard-rail and the track-rail, securely spiked to the ties, and with ends running to a point in the center of the track on the side from which trains approach. The distance of this point from the end of the bridge should vary in different cases, but should not be less than 30 ft., and preferably 60 ft. on important bridges. If the approach is on a curve, the guard-rail should be carried further; and on sharp and short curves it is advisable to extend them entirely around the curve, or to run them to a point 30 or 60 ft. from the bridge, and from this point to carry a single rail in the center of the track around the curve. The point of the guard-rail should be protected by an old frog point or by a bevelled wooden block to prevent any hanging chain from catching on the end. The distance between the track and the guard-rails should be sufficient to allow a wheel to run between them without crowding either rail, or from 7 to 10 in.

The Board consider that this form of guard-rail is much more efficient than the outside guard-rail in bringing a derailed truck back to its proper position. On many roads the outside guard-rails extend but a short distance beyond the ends of the bridge, and are frequently curved abruptly so as to be nearly at right angles with the track. Furthermore, the long ties on which such guard-rails rest are generally insufficiently bedded in the ballast outside of the rails. The tendency of such a guard-rail is to stop the wheel which strikes it and to twist the truck still further, placing it at a greater angle with the track, and thus tending to increase rather than to diminish the danger of an accident. The Board consider such guard-rails to be worse than useless, and recommend that they be replaced by inside guard-rails without delay. Outside guard-rails of proper length, slightly curved and properly laid, may accomplish their intended purpose, but they are wrong in



THE NEW CANADIAN PACIFIC STATION AT MONTREAL.

BRUCE PRICE, NEW YORK, ARCHITECT.

principle, because they are struck by the wheel at the wrong end of the axle, and if they do their work at all, they do it at great disadvantage.

The objection is sometimes urged against inside guard-rails that a mischievous person may place an obstruction between the guard and track-rails, or that some obstruction may accidentally get there. The Board believe that this argument has no practical weight, and that even if a truck were derailed in this manner it would, by virtue of the guard-rail, pass safely across the bridge. A person who desires to wreck a train can find abundant means of doing it more effectual than this. Further objections are sometimes pleaded that the use of the snow-plow is rendered difficult, or that a hanging chain may catch on the point of the guard-rail. These also appear to the Board to have little weight. The points may be protected as already explained, and the use of the snow-plow is no more interfered with than at any turnout or crossing. Finally, it is sometimes urged that a truck, if derailed far enough to get on the wrong side of the point, would be still further deviated by the guard-rail.

As long as a train holds together it is very rare for a truck to be off the track more than a few inches or a foot. If the train has parted and a truck is off by as much as one-half of the gauge, the wheels on one side of this truck would be off the ties and a smash-up could hardly be averted, no matter what shape of guard-rail were applied. Certainly the ordinary form of outside guard-rail would do no good. Furthermore, the possibility of such an accident at a bridge may be almost completely removed by extending either the guard-rails or a single guard-rail on curved approaches, as has been suggested.

THE CANADIAN PACIFIC STATION AT MONTREAL.

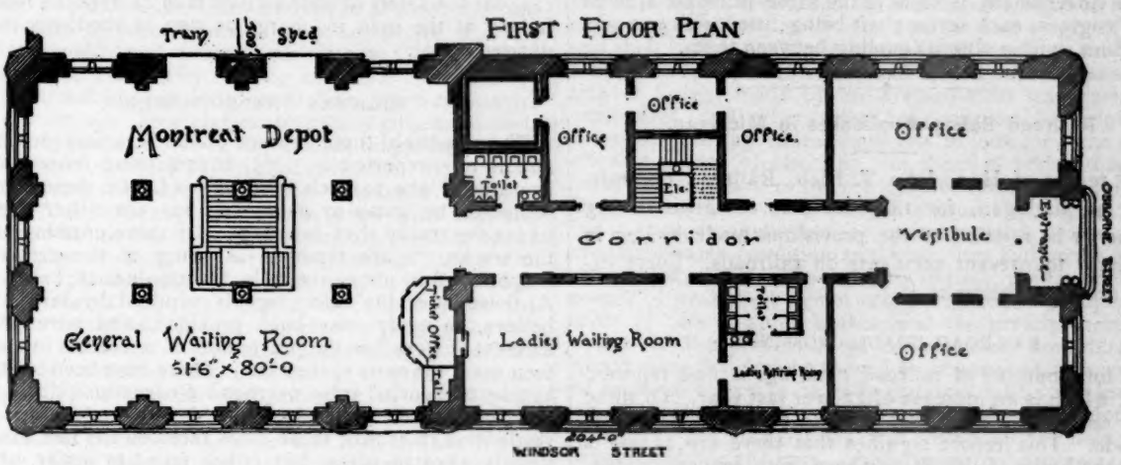
THE accompanying illustrations (for which we are indebted to the courtesy of the *Engineering and Building Record*) show a general view and the first-floor plan of the new passenger station of the Canadian Pacific Railroad at Montreal. As will be seen from the engraving, the building stands on rising ground, the basement being a full story at one end and wholly underground at the other. There are four full stories above the basement, besides a finished story in the roof. The general dimensions of the building are 204 ft. front and 70 ft. deep.

The train shed, in the rear of the main building, is 500 ft. long.

The material used in the building is stone, Scotch rubble-face, with rock-face belt courses. The interior finish is in Vancouver cedar. The general waiting-room, on the first floor, is arched over, with granite columns and arches finished in plaster. The floor-beams throughout the building are iron, with fire-proof finish.

The accompanying plan shows the arrangement of the first floor. The upper floors are used for the offices of the company.

The architect, Mr. Bruce Price, of New York, has designed a building very pleasing in its general effect and apparently well suited for its purpose. The cost of the new station is about $250,000 in all.



THE CANADIAN PACIFIC STATION AT MONTREAL.

The Separation of the Passage and Emergency Powers for Warships.

[Paper read by Chief-Engineer N. B. Clark, U. S. N., before the United States Naval Institute.]

A MODERN warship should have sufficient motive power to drive her at least 20 knots per hour in an emergency, such as chasing an enemy, or escaping from a superior force.

Her engines should also be designed so that while steaming from port to port they may function with the utmost economy at one-half that speed, at which she would consume, under ordinary circumstances, as much as 95 per cent. of her fuel. As the sea endurance of the vessel depends so largely upon her economy of fuel at a low speed, the importance of the subject to a navy with few coaling stations needs no comment.

As the attainment of 20 knots per hour requires approximately eight times the power necessary to attain a speed of 10 knots, it will be readily understood that the two powers cannot be developed with equal economy in the same cylinders.

Soon after the organization of the Naval Advisory Board, under whose auspices the *Chicago*, *Boston*, *Atlanta* and *Dolphin* were constructed, I submitted to that body the plan herein described, and urged it upon them as the type of motive power for the new ships.

Each vessel was to be fitted with twin screws, with two separate sets of engines on each screw shaft. The after engines were to be of a high grade of expansion proportioned to the development of the passage power, or about one-eighth of the whole power with which, with the utmost economy of fuel, a speed of 10 knots could be attained. The forward engines on each shaft were to be of a lower grade of expansion, in order to secure lightness of structure, and were to be proportioned for the development of the emergency power, which would be but seldom used. The screw shaft between the two sets of engines was to be fitted with a clutch coupling, whereby the emergency power engine could be readily connected, or disconnected, as occasion required.

An alternative plan submitted was to connect both sets of engines to a counter-shaft, and gear them to the screw shaft with friction gearing. The latter plan presented the advantage of not transmitting the emergency power through the passage-power cranks, and permitted any one of the four engines to be used for propelling the ship, in event of casualty to the others. Under ordinary circumstances the ship while cruising would be driven by her passage-power machinery, thereby avoiding the loss incident to the development of a small power in a large engine.

I also proposed to the Board that two different types of boiler be fitted in each ship. Steam for the passage power was to be generated in boilers of the ordinary durable cylindrical type; while the steam for the emergency power, which would be but seldom used, was to be generated in the far lighter, but less durable locomotive, or Herreshoff type.

By this means a great saving in the weight of machinery could have been attained—sufficient, in fact, to have fitted the vessels with invulnerable deflective V-shields which would have completely protected the men working the guns, as well as the ammunition in its passage to the guns.

The British Government has adopted the plan of separate boilers in their new ships, and, according to Mr. F. C. Marshall, the armor-clad *Sardegna*, now building by the Italian Government, is to have the same principle applied to her engines, each screw shaft being fitted with two sets of engines, with a clutch coupling between them.

Railroad Safety Appliances in Michigan.

THE report of Hon. John T. Rich, Railroad Commissioner of Michigan, for 1887 contains some interesting statements in relation to the provisions made by law in that State to prevent accidents on railroads. Some extracts are given below:

RAILROAD GRADE CROSSINGS.

The total number of railroad crossings is now reported at 230, which is an increase of 27 over last year. Of these 21 are either over or under, and the remainder, 209, are at grade. This report signifies that there are 55 points within the limits of this State where, with two exceptions, all trains should be brought to a full stop when approaching the same. This requirement has been incorporated into our laws in the interest of the public safety and for the protection of railroad employés and the property entrusted to their charge as well. Generally, I believe, the law is obeyed, but sometimes it is otherwise, and at all times its observance involves delay and great wear and tear of cars and fixtures. To avoid the necessity of making such stops, without prejudice to the safety of the trains and the people upon them, has engaged the attention of inventors and resulted in the perfecting of a device which seems to answer the required conditions and is rapidly becoming an important appliance for the protection of railroad crossings; it is known as the "Interlocking and Derailing Switch." . . . .

The advantages gained by the interlocking switch are the nearly or quite absolute protection against crossing collisions, the saving of time in stopping trains, and power and fuel to start, and the general wear and tear to track and rolling stock in stopping and starting. The expense of interlocking and derailing switches has been so large in the past, that railroads have been reluctant to adopt them, but the expense is now materially reduced, and their voluntary adoption by the railroad companies will be much more frequent than in the past. The first interlocking switch used in this State was put in at the crossing of the Grand Rapids & Indiana and the Air Line Division of the Michigan Central at Wasepi, in 1884; one at the crossing of the Mineral Range and the Hancock & Calumet, near Calumet, in 1885; one at the crossing of the Detroit & Bay City and the Flint & Pere Marquette branch at Saginaw, in 1886. All of these have proven satisfactory in their operation, and no accidents have occurred at any of them. There has never been but one derailment at these switches that has come to the knowledge of this office, since they have been in use. During the present season there have been put in voluntarily by the railroad companies a full interlocker at the crossing of the Michigan Central and the Chicago & Grand Trunk at Nichols, and a second-class interlocker at the crossing of the Chicago & West Michigan and the Toledo & South Haven at Hartford. And there are now in process of erection, also by the voluntary action of the railroad companies, an interlocker at Lansing at the crossing of the Michigan Central and the Lake Shore & Michigan Southern tracks, across the Chicago & Grand Trunk. It is also understood that the Michigan Central and the Grand Rapids & Indiana contemplate putting in one at their crossing at Kalamazoo in the near future.

By the provisions of act No. 236 of the session laws of 1887, the Crossing Board, consisting of the Commissioner of Railroads, the Attorney-General, and the Secretary of State, are required to approve of all maps of proposed new railroads, and if such route cross the track of any other railroad, to determine whether such crossing shall be at grade or otherwise, and if at grade what safeguards shall be provided against accidents. Under this provision of law the Board have required interlockers to be put in at 11 different points, subject to the approval of the Commissioner of Railroads, and provision will be made in every case for the safety of trains which may be derailed through failure of the men in charge to stop in obedience to the danger signal.

HIGHWAY GRADE CROSSINGS.

The number of these exposed points is rapidly increasing and is now reported at 5,965, or something more than an average of one to each mile of road. Of these 227 are protected by gates or flags, and 177 are either over or under the tracks they intersect. Of those crossing above the tracks, 77 are reported as being of the prescribed height of 18 ft. above the rails, the residue, 21, being less. At these latter the safety signals required by law have, I believe, in every case been provided, and have proved efficient devices for the prevention of accidents to brakemen upon the roofs of the cars. There have been but three accidents reported from overhead obstructions during the year, one person having been killed and two injured. Investigation in each of these cases revealed the fact that the signals were in place, but either failed to notify, or the unfortunate trainmen failed to heed their friendly warning.

Accidents at street and highway crossings are of too common occurrence, and frequently with fatal results. Eight persons were killed and 14 injured at such crossings during the year. There are now a large number of men employed as flagmen and gate-keepers at this class of crossings. When flagmen only are employed there have been some very serious accidents; in some instances the men being temporarily absent from their posts, and people not seeing the flagman, concluding everything was all right, have been struck by the train. In other cases the flagman has been unable to control people and they have been injured. Where gates are used there has been less trouble, but even then, where there are several tracks, teams have been allowed to pass upon the crossing, and before reaching the gate at the further side it has been closed so as to prevent their escape from accident either through fright of their teams or by being struck by a passing train.

There are now on trial automatic electric bells which are rung by the approaching train. They have been only a partial success, but with some improvements they have much to recommend them. If they are properly constructed their action is not dependent on any one's care or presence, they act at all hours of the day and night. Their warning is timely, and the expense of maintenance is much less than to employ a flagman, with or without a gate, or to build a bridge. But there are places where the bell could not be made to answer the purpose. Where the view at the crossing is unobstructed, it is probably safer for people to rely upon their own precautions, rather than to depend on any device for warning them of danger, for none of them are infallible.

AUTOMATIC COUPLERS.

The Legislature of 1885 passed an act requiring all railroad companies to use some form of automatic or safety coupler at each end of all freight cars which they might buy or lease, and upon all old cars sent to the shops for repairs. The same act required the Commissioner of Railroads to select "two or more different patterns of automatic or safety couplers which will couple with each other and with the link-and-pin coupler now generally in use, from which patterns said railroad companies may select couplers for use on cars," as required by said act. Under the provisions of this act, my predecessor selected couplers of seven different patterns, from all of which more or less have been put on freight cars for use in this State.

After something more than a year's experience with them, the result has not been the most desirable. There has been no considerable diminution in the number of coupling accidents, and we are, if possible, no nearer to uniformity than before. Railroad managers have not, apparently, taken the active interest in the subject which might be expected, and the law has not been very strictly obeyed. Even if it was, so far as the cars owned and controlled by railroad companies wholly or partly within this State are concerned, the number of foreign cars used, over which the State has no control, is so great that the same difficulty would remain. An attempt to prevent the running of cars of other States without complying with the State law would be of doubtful expediency, for if enforced it would simply result in causing such cars to be sent by other lines, making a serious loss to the railroad companies of this State, and depriving many of our citizens of their present employment. Then there is no disputing the fact that the men for whose safety and protection the Legislature required the adoption of the automatic or safety couplers (the brakemen) are not satisfied with anything now in use in this State. All the couplers selected by the Commissioner of Railroads were supposed to couple with each other automatically, or at least without the necessity of going between the cars to make the coupling, and also with the ordinary link-and-pin coupler by placing the link in the old drawhead. Repeated observation has shown that very few couplings are made except by going between the cars. It is the universal practice in coupling an ordinary coupler with an automatic, to place the link in the latter and guide it into the former with the hand. To ask why this is done brings the uniform reply that "the automatic is no good;" that "they don't work half the time, and that they had rather do it the old way and be sure." The coupler having the most friends among brakemen is one presenting a concave space on the lateral sections of the face of the drawhead for the protection of the hand while guiding the link to make the coupling. In other respects it is simply the ordinary link-and-pin drawbar. With one exception the couplers selected for use in this State are what are known as link couplers. The reasons for this undoubtedly were that until very recently most railroad men have considered the link necessary to a freight coupler, and as no device was adopted without the approval of one or more railroad managers, it is to be supposed that the selections were made in accordance with the ideas of practical railroad men. The law also required all the couplers to couple with the link-and-pin coupler in general use, and automatic link couplers generally do this more successfully than those which dispense with the link.

The Legislature of 1887 amended the act of 1885, so that the railroad companies might use any coupler which came up to the standard fixed by the law of 1885, and was approved by the Commissioner of Railroads. Under this act no new couplers have been added to the list for use in this State, and only one application has been made by any railroad company for the approval of any coupler. That was made by the Grand Rapids & Indiana Railroad Company for the approval of the Janney, which is a vertical hook coupler, and makes a close coupling, similar to those used on passenger cars. Approval was withheld, because it could not be coupled with the ordinary link-and-pin coupler without going between the cars, and from the shape of the end of the drawhead seemed more than usually dangerous to couple by hand, hence the approval of it for use was deemed to be in violation of the spirit if not of the letter of the law. No objection appears to its use when it couples with its kind.

Since this action the Master Car-Builders' Association of the United States has, by a vote of more than two-thirds of its members, adopted couplers of the Janney type, and those that will couple with them, as the standard for uniform use throughout the United States, and are making a determined effort to have it generally adopted. The Janney has been used more or less on the Pennsylvania Railroad for some years, and is met with frequently in this State on the cars of that company, especially on the Grand Rapids & Indiana Railroad. It is also used extensively by the companies carrying dressed meats on their refrigerator cars, and running more or less on all our roads, and especially on the Michigan Central and the Chicago & Grand Trunk. If adopted for general use it does away with the link and its consequent loose coupling, and substitutes the close coupling, heretofore supposed to be adapted only to use on passenger cars. In view of these facts it is a question whether approval for its use by the railroad companies of this State should be longer withheld by this department.

POWER BRAKES.

The number of trains which it has become necessary to run on a single track, and the additional weight of trains caused by the increase in both number and weight of cars and their lading, the numerous railroad crossings at which trains must stop, and the demand for the rapid transportation of freight made by the dressed-meat transportation companies, and others who have perishable freight to move, are causing railroad officials to look for some more efficient means of checking the speed of trains than the hand brake. Some of the refrigerator lines have equipped their cars with the air-brake, but if drawn by engines lacking the proper appliances for operating such brakes, they are in the same condition as though they had no air-brake attachment. When the economy in time, the lessened exposure of brakemen by not being required to go upon the roofs of cars to apply brakes, and the greatly increased power for the prevention of collisions are considered, it would seem that freight as well as passenger trains should be required by law to be fully equipped with some kind of power brake. Another reason why this should be done is, that there are many trains run, composed of both passenger and freight cars, which seem to be necessary to save unnecessary expense to railroad companies and for the accommodation of the people. Yet at present they are entirely dependent upon the hand brake unless the engine is equipped with power brakes, which is not the rule at present. This class of trains have day cars, and in some instances sleeping-cars are attached, and are provided with no efficient means of checking the speed of the train in case of an accident. The law provides that no baggage or freight car shall be placed in the rear of a passenger car.

Another section of the law provides that no regular passenger train shall be run without an air-brake or some equally effective device for checking the speed of the train, which may be applied to each passenger car composing the train. If this class of trains are regular passenger trains, then they must have the air-brakes, and when they run regularly and are advertised as passenger trains they may be reasonably considered as such, even though they do take freight as well. There should certainly be some means provided for this class of trains, and the requiring all trains of every description to be equipped with power brakes would be almost the only effective means to accomplish it.

Trials recently made at Chicago, St. Louis, and other places conclusively demonstrate the practicability and advantage of having freight trains fully equipped with some form of power brake.

CAR HEATERS.

By act No. 118 of the session laws of 1887, it is provided, "That on and after the first day of November, 1888, every railroad company owning or operating any railroad wholly or partially within this State shall make some effective provision against the burning of cars in which passengers

are carried, in some one of the following or equally effective methods: By generating the heat for warming the cars outside and independent of said cars, or by enclosing the heater in a closet or room made of boiler-iron, or some other material which will afford equal protection against the car taking fire, or some device by which the fire will be effectively and quickly extinguished in case the car is overturned."

The intent is evidently to avoid heating cars with what has come to be known as the "deadly car stove." Various devices will be tried during the coming winter, and there is no doubt that the experience gained during the winter of 1887–88 will go far toward determining the principle upon which cars will be heated in the future. Some plan of taking steam from the locomotive seems to have more friends at the present time than any other.

LOCOMOTIVE BOILER EXPLOSIONS ON BRITISH RAILROADS.

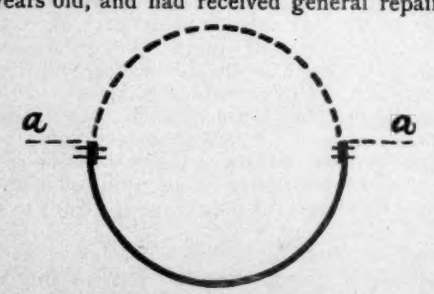
(*Continued from page 27.*)

WE continue below the summary of the Inspectors' reports to the British Board of Trade on accidents resulting from the failure of locomotive boilers.

INSPECTORS' REPORTS.

January 8, 1872, the boiler of a locomotive drawing a freight train on the Glasgow & Southwestern line exploded near Fochabers. The train had started from the station a minute before, and at the time of the explosion was running down grade, using very little steam. The crown-sheet of the outer shell of the fire-box, a plate of $\frac{9}{16}$-in. iron about 6 ft. 8 in. by 5 ft. 3 in., was completely torn off and separated into three portions, two large and one small. A large triangular piece of one of the side-sheets was also torn out, and the other side-sheet was doubled down over the frame. A brakeman, who was on the engine, was killed, the engineer and fireman badly hurt. The engine had 17×22-in. cylinders, four-coupled drivers 5 ft. diameter, and leading wheels 3½ ft. It was nine years old; the boiler had been four times repaired, the last time only two months before the explosion, when 20 new stay-bolts were put in. At that time the safety-valves were tested and fixed at 120 lbs., but no test was made of the boiler. A careful examination of the boiler showed no indications of corrosion serious enough to cause the explosion. The top row of stay-bolts was somewhat defective. The iron plates were generally good, except that some indications of crystalline fracture were found in the throat-sheet. The Inspector believes that this weakness and the defective stay-bolts caused the explosion; he thinks that the boiler should have been subjected to a hydraulic test when repaired.

February 5, 1872, the boiler of the engine of a coal train on the Whitehaven, Cleator & Egremont road exploded at Moor Row station. The engineer was killed. The engine had six wheels coupled and a saddle-tank. It was 10 years old, and had received general repairs about



four months before, but the boiler was not then examined. A new set of tubes had been put in 2½ years before, and a careful examination had then showed no serious defects. The barrel of this boiler was 50 in. diameter and about 13 ft. long; it was made with two plates in its girth, the joints of those next the fire-box being opposite each other in a horizontal plane passing through the axis of the boiler; the joints overlapped, the lower over the upper plate, about 3½ in., and were double riveted, the rivets having 2½ in. pitch. The vertical joints were single riveted. The plates were of $\frac{7}{16}$-in. iron and had been very little reduced by wear. The accompanying sketch shows a section of the barrel of the boiler, the dotted portion showing the plate which was blown off. Examination showed that the rupture took place in a straight line along the joint, and it appeared that the plate was deeply corroded along this line, the sheet at some points being only from $\frac{1}{8}$ to $\frac{1}{8}$ in. thick. There was also a good deal of pitting at other points. The reason of the explosion was therefore very evident; the only wonder was, in fact, that the boiler held together as long as it did. The Inspector believes that proper inspection would have shown the weakness of the boiler.

September 16, 1872, the boiler of a locomotive on the Dublin, Wicklow & Wexford road exploded while the engine was standing at Bray station. It was a six-wheel tank engine, with one pair of drivers 5½ ft. diameter, leading and trailing wheels 3½ ft. The boiler was 48 in. diameter of barrel and 10. ft. long. It was of $\frac{3}{8}$-in. iron, single riveted, with $\frac{3}{4}$-in. rivets pitched 1¾ in. The barrel was torn completely away from both smoke-box and fire-box, and separated into no less than 21 pieces, which were thrown off in all directions. Some evidences of corrosion were found, the bottom of the barrel being reduced at some points to about $\frac{3}{16}$ in. The man-hole casting and plate the Inspector thought too weak. The evident cause of the explosion, however, was over-pressure, and there was evidence that the safety-valve had been wedged down by the engine-driver, who was killed.

August 22, 1873, the boiler of the locomotive of a goods train on the South Devon Railway exploded just after the train had stopped at Brent station. The engine was a tank engine with 17×24-in. cylinders and six 57-in. wheels, all coupled. The boiler barrel was 10 ft. 2 in. long and 53 in. diameter, of $\frac{1}{2}$-in. iron plates, single riveted with $\frac{3}{4}$-in. rivets spaced 1¾ in. apart. The engine was provided with one pump and one injector. The steam dome and tank were blown clear away; the center ring of the boiler and part of the ring next to the fire-box opened at the top, and the plates were folded back at each side, leaving the tubes bare; they were very slightly injured. The front plate of the fire-box was slightly bulged forward at each side near the top. The engineer, fireman, and a boy standing by the track were scalded. The evidence indicated that the injector was out of order, that the pump had not been put on, and that water had been allowed to get low in the boiler. When the engine stopped at Brent the injector began to work again, and the explosion was caused by the sudden and rapid generation of steam when the water began to flow into the boiler.

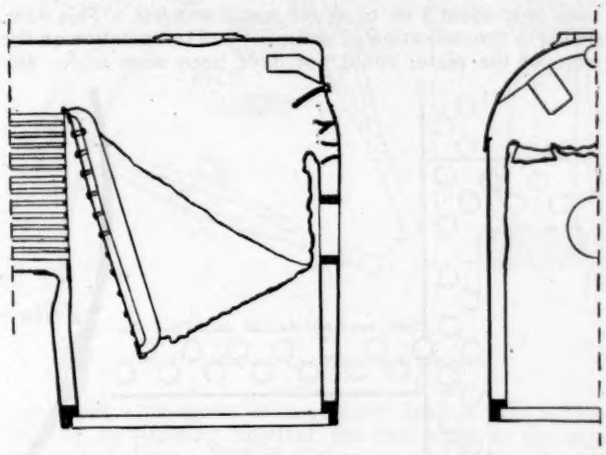
August 25, 1873, the boiler of a goods engine on the Taff Vale road exploded at Cardiff Dock, while the engine was waiting to go out with a train. The whole barrel was blown away by the explosion; one piece of plate was turned over and remained hanging to one side of the fire-box shell and another plate remained hanging to the smoke-box. The rest of the barrel was torn into six pieces, which were thrown off in different directions. The working parts of the engine were badly damaged. The engine had 16×24-in. cylinders and six 56-in. wheels, all coupled. The boiler was 50 in. diameter and 10½ ft. length of barrel, of $\frac{7}{16}$-in. iron plates, lap-jointed, with $\frac{3}{4}$-in. rivets, spaced diagonally, 2¼ and 1⅝ in. apart. It was nine years old. About two years before the explosion new tubes, new tube plates, and three new plates in the barrel were put in, two of the latter forming the ring next the smoke-box, the third the lower part of the middle ring. The under plate next the fire-box was pitted, but was thought good enough to remain, but a patch or liner-plate 21 in. by 9 in. was riveted on it to stop further pitting. The Inspector says in this case:

"The method adopted in putting on the patch or liner-plate reduced the strength of the bottom plate of the boiler, which was already defective, about one-half, and there can be no doubt that it exploded from the weakness created by this work.

"It is always a mistake to patch locomotive boilers. The expense, in the present case, of the three new plates

and the patch was probably greater than if the boiler had been renewed."

May 22, 1874, the boiler of a goods engine on the Great Western Railway exploded near Aberdare. The engine was used to work a short coal branch, and at the time of the explosion had been running backward down a very heavy grade, but had stopped on account of the train breaking in two. Both engineer and fireman were killed; two other employés were hurt. The engine was thrown back along the track over 200 ft., and then went off on one side of the rails. The engine in this case had 16×24-in. cylinders and six 54-in. coupled wheels. The boiler was 11 ft. long and 48 in. diameter of barrel; the fire-box was 5 ft. 2 in. long and 4 ft. 1¼ in. wide outside; 4 ft. 6⅝ in. long, 3 ft. 6¼ in. wide, and 5 ft. 2 in. high inside. There were 235 tubes 1⅝ in. diameter and 11 ft. 5 in. long. The outer fire-box shell was of $\frac{7}{16}$-in. iron, the inner shell of $\frac{7}{16}$-in. copper. As will be seen from the accompanying sketch, taken after the explosion, its force was entirely in

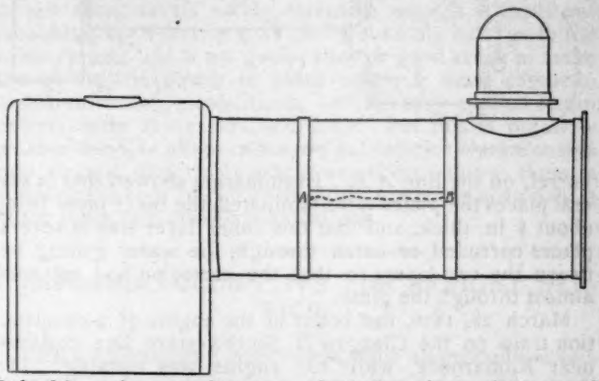


the fire-box. The crown-sheet was torn from the side-sheets and forced down against the tube-sheet, the roof-stays or crown-bars going with it. The sling-stays by which the roof-stays were held to the outer crown-sheet were all broken. The outer iron shell of the fire-box was bulged out of shape, as shown, but was not seriously damaged. None of the crown-bars were broken, although some of them were bent. The fracture took place along the edges of the copper crown-sheet. The back-plate of the fire-box was also torn out of shape. No evidences of serious corrosion or weakening of the plates could be discovered. It appeared that the steam-gauge had been taken off for repairs, and that the engine was running at the time without a gauge. The Inspector believes that the explosion was caused probably by high pressure and low water, and finds much fault with the absence of the steam-gauge.

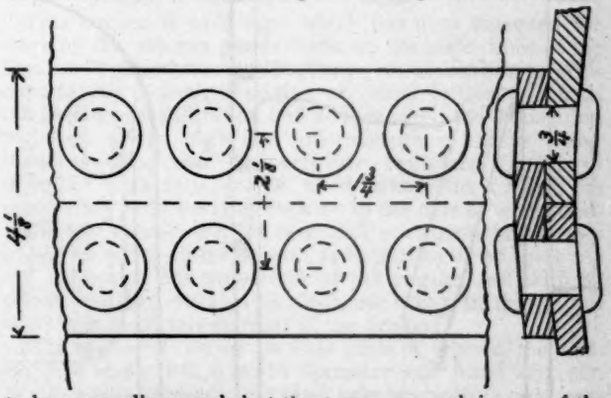
November 28, 1874, the boiler of a shifting engine on the Lancashire & Yorkshire road exploded in the yard at Leeds. The engine was a tank engine with a boiler 48 in. diameter of barrel and 11 ft. long. The explosion took place in the first ring next the smoke-box, and the plates were generally torn apart along the lines of rivets. The boiler had not been overhauled for six years, but some six months before, when other repairs had been made to the engine, it had been tested up to 170 lbs.; the usual working pressure was 120 lbs. Examination showed much corrosion, the barrel plates having been reduced in places from $\frac{7}{16}$ to less than ⅜ in. There was no appearance of undue heating or low water, and the explosion was probably due to the weakness caused by the corrosion. The Inspector censured the long time allowed to pass without a full examination of the boiler.

February 26, 1875, the boiler of a shifting engine on the Northeastern road exploded at Middlesboro, injuring three men. The rear end of the engine was lifted up and thrown off the rails. The engine was 18 years old, but the boiler had been repaired and a new sheet put in the fire-box three years before. In this case a piece of the copper side-sheet of the fire-box about 4½ by 2 ft. was torn out, and he fire-box was much distorted in shape. This was a case of corrosion and general weakening; the copper plate had been worn down from ½ in. to less than ¼ in., and of 44 stay-bolts in the broken piece of the sheet only 12 retained their hold. There were in all 80 stay-bolts in the side-sheet, and of these only 18 remained good and kept their hold on the sheet.

June 26, 1875, the boiler of the engine of a goods train on the Manchester, Sheffield & Lincolnshire line exploded at Dodworth, injuring two persons. The barrel of the boiler was almost completely broken up, the pieces being thrown in different directions, one or two of them to a distance of 650 ft. The engine had 18×24-in. cylinders and six 5-ft. wheels, all coupled. The boiler was 51 in. diameter of barrel and 10½ ft. long; it was 15 years old.



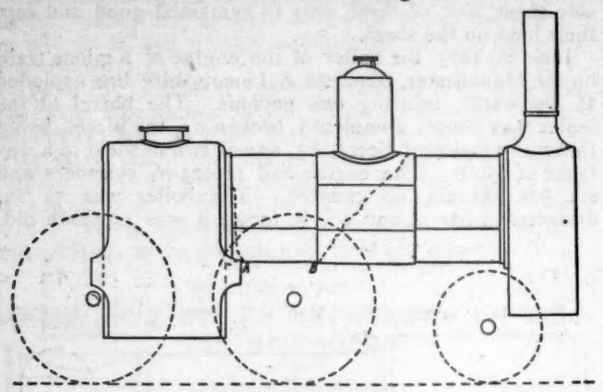
It had been inspected two months before the explosion and found to be in good condition. It was of ½-in. iron plates with butt joints, the edges of the plates being planed and the joint covered on the outside by a welt or strip of ½-in. plate, 4 in. wide. There were two rows of rivets ¾ in. diameter spaced 1¾ in. The caulking was done inside, on the planed joints. The accompanying sketches are a general view of the boiler, and (on a larger scale) a short section of a joint. After the explosion the plates were found



to be generally sound, but there was a crack in one of the cover-strips about 34 in. long and extending nearly half way through the strip. The explosion is believed to have started in this cracked strip, on the line *A B* in the diagram. The Inspector thinks that there is no way of ascertaining the existence of a defect of this kind, and believes that it would be of little use to make the strips thicker. He says: "The apparent lesson to be learned from this explosion is in favor of giving up the use of butt joints covered with strips or welts in the construction of the barrels of boilers."

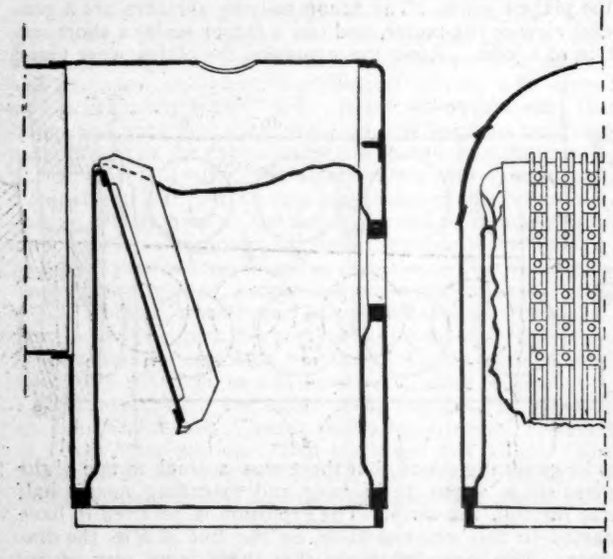
July 23, 1875, the boiler of the engine of a passenger train on the Northeastern line exploded while the train was standing at Holbeck station, injuring the engineer, the fireman, and two men who were standing near. The rear end of the barrel of the boiler was torn to pieces, and the engine was pretty well demolished. Pieces of the boiler were thrown in all directions, one landing some 600 ft. away. The engine had 15×22-in. cylinders, four coupled wheels 6 ft. diameter, and leading wheels 4 ft. diameter. The boiler was 46 in. diameter of barrel and 10½ ft. long; it was of $\frac{7}{16}$-in. iron plates and was worked usually at 120 lbs. pressure. The engine was 22 years old, and had received general repairs two years before.

The accompanying sketch is a general view of the boiler, the dotted lines showing approximately the lines of fracture. The fracture also extended along the bottom of the



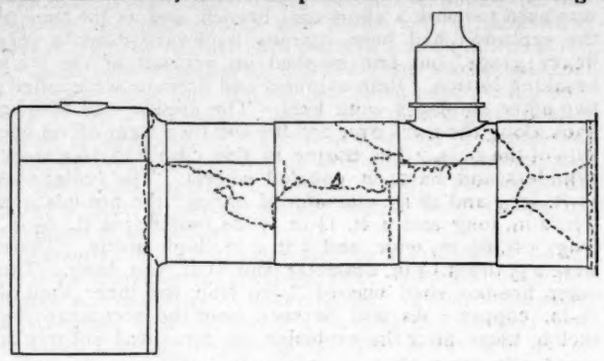
barrel, on the line *A B*. Examination showed that in several places the plates were laminated, the inner layer being about ¼ in. thick, and that this inner layer was in several places corroded or eaten through, the water getting between the two layers so that the corrosion had extended almost through the plate.

March 28, 1876, the boiler of the engine of a construction train on the Glasgow & Southwestern line exploded near Kilmarnock, while the engine was running. The crown-sheet of the fire-box gave way, and the force of the explosion lifted the engine up and threw it over on a car, which was broken to pieces. The engineer, fireman, and guard were killed. The accompanying sketch gives a longitudinal and half cross-section of the fire-box, showing the condition in which it was left after the explosion.

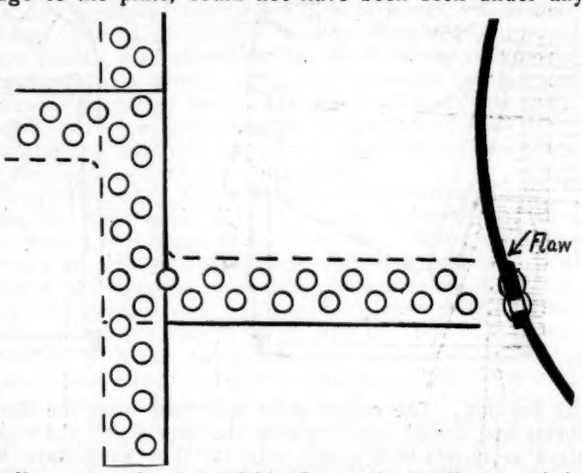


From the examination the Inspector concluded that the boiler was in good condition, and that the explosion must be attributed to low water, the crown-sheet having been overheated, and then unable to resist the pressure from the rapid generation of steam when water was pumped in. He also thought that the boiler was defective in having no vertical stays to connect the crown-bars with the outer shell; such stays might have prevented the explosion. The engine in this case had 16×22-in. cylinders, four coupled wheels 60 in. diameter and 42-in. leading wheels. It was 18 years old.

March 28, 1877, the boiler of the engine of a goods train on the Northeastern line exploded while the engine was taking water at Alne. The upper part of the barrel was completely destroyed, and eight pieces (the largest about 5 by 3 ft.) were blown off in various directions, one falling 540 ft. away. The boiler was 12 years old, of $\frac{7}{16}$-in. iron, and had been repaired three years before. The accompanying sketches show the boiler, the dotted lines showing the lines of fracture, and (on a larger scale) part of a seam, showing the method of riveting. On the upper edge of one of the plates (at about the point marked *A*) there was found a flaw, where the plate had been eaten through



until only about ⅛ in. of sound metal was left. This flaw, owing to the collection of sediment and incrustation on the edge of the plate, could not have been seen under any



ordinary examination. This flaw undoubtedly caused the explosion. The Inspector says: "The practice of arranging the plates of boilers so that the lower pass inside the upper, by which rest-joints are introduced, in which deposits take place, preventing the discovery of flaws, does not seem to be judicious."

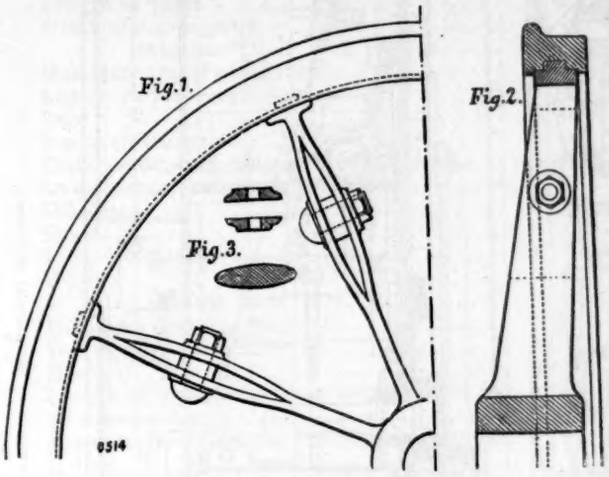
September 11, 1877, the engine of a passenger train on the Great Western road exploded its boiler at Oakengates, killing the engineer and injuring the fireman. The explosion is thus described by the Inspector: "The midfeather is a partition across the lower part of the fire-box, which contains water. Its object is to give more heating surface, promote the circulation of water, and assist in consuming smoke. They are not generally used in narrow-gauge engines. In the present case the midfeather was of ½-in. copper plate, like the rest of the fire-box, and was stayed with solid 1-in. copper stays and copper tubes, which were screwed into the plates, the ends being hammered down to assist in holding them fast. The plate at the front end of the midfeather had been reduced by wear to a thickness of a little over ⅛ in., the thinnest part being about the level of the top of the fire. The stays were pulled through the plates by the pressure of steam and water inside the midfeather, and the water rushed through the holes into the fire. An explosion of steam occurred, which broke down the ashpan and fire-bars, rushed through the fire-door, and knocked the engineman and fireman into the tender. . . . The accident was caused by the plates being so much reduced in thickness that they could not hold the stays."

The reports of all the companies for the year 1877 show that during that year there were four accidents due to failure of boilers or parts of boilers, by which two persons were killed and two injured. Two of these accidents were reported on; the other two were slight, caused by failure of tubes.

(TO BE CONTINUED.)

Interchangeable Steel Wheel for Street Cars.

THE accompanying engraving, from the London *Engineering*, shows a new form of wheel for street-cars, in which the tire can be removed from the center and replaced, when worn, with very slight trouble, and without taking the wheel off the axle. The center of the wheel is cast in one piece of mild Swedish crucible steel, and each spoke has an oval-shaped opening running lengthwise near its outer end. When the wheel is to be put together the center is placed inside the tire, which is rolled of cast-



STEEL TRAMWAY WHEEL.

MADE BY HANSELL & CO., SHEFFIELD, ENGLAND.

steel, and each spoke is lengthened until it gets a firm bearing, by drawing together the two sides of the oval mentioned above. This is effected by steel bolts and nuts, the amount of compression being regulated by a broad spring washer placed between the two members of the spoke. In order to make the connection between the arms and the tire more secure, the ends of several of the arms are circular for a distance of about ¼ in., and fit into corresponding recesses formed internally in the tire. The center can be removed and fitted with new tires as often as required.

Electric Motors—The Wrong Way and the Right Way.

(From the *Electrical Engineer*.)

A WELL-KNOWN electrician of our acquaintance had occasion a short time since to consult a manufacturer of locomotives, whose street-railroad motors have attained a national reputation for economy and general efficiency, with reference to the construction of an electric motor. The manufacturer at once exclaimed that it was useless for him to estimate on electric machinery, as he had found by experience that electrical people would not pay for the quality of workmanship that was required for proper locomotive running gear. What they wanted, he said, was a cheaper class of work, such, for example, as that used in a rather poor grade of agricultural implements.

This remark might well furnish a text for a very instructive sermon. If a locomotive is to haul a certain load over a given track, it is certainly very poor economy to use less perfect running gear for an electric than for a steam motor. Yet many electric motors which we have seen are eloquent witnesses to the truth of the remarks of the locomotive builder. And as if this were not enough, we have noted a certain disposition on the part of some electric-railroad people to undertake what may be called feats of sensational engineering, such as running over imperfect tracks, and up and down impracticable gradients, and the like. There is no reason whatever to suppose that an electrically driven locomotive can run with safety where a steam driven one cannot, yet it is quite apparent that many people who ought to know better are being carried away with the delusion that any railroad problem that presents peculiar difficulty can be solved at once by the application of electricity, just as we heard it gravely argued, during the prevalence of the narrow-gauge craze some years ago, that a locomotive of 3-ft. gauge could ascend a steeper incline, other things being equal, than one of 4 ft. 8½-in. gauge. We hear, for instance, of one line on which an attempt is to be made to work grades of over 700 ft. per mile with electric locomotives, for passenger service. Unless special precautions are taken, as, for example, on the Mt. Washington or Mt. Cenis inclines, to undertake such a feat is to invite disaster.

The legitimate field which is now open to the electrically driven street-car is surely extensive enough without encroaching upon territory which legitimately belongs to the cable system. It is not good policy or good sense to make use of electric power in cases where it must compete, under unfavorable conditions, with directly applied steam power under favorable conditions. But this is precisely what is done, in effect, when we put inferior workmanship into electric motors, or when we attempt to use them in situations where an inclined cable system is obviously a much more safe and economical one.

COMPOUND LOCOMOTIVE FOR FREIGHT SERVICE.

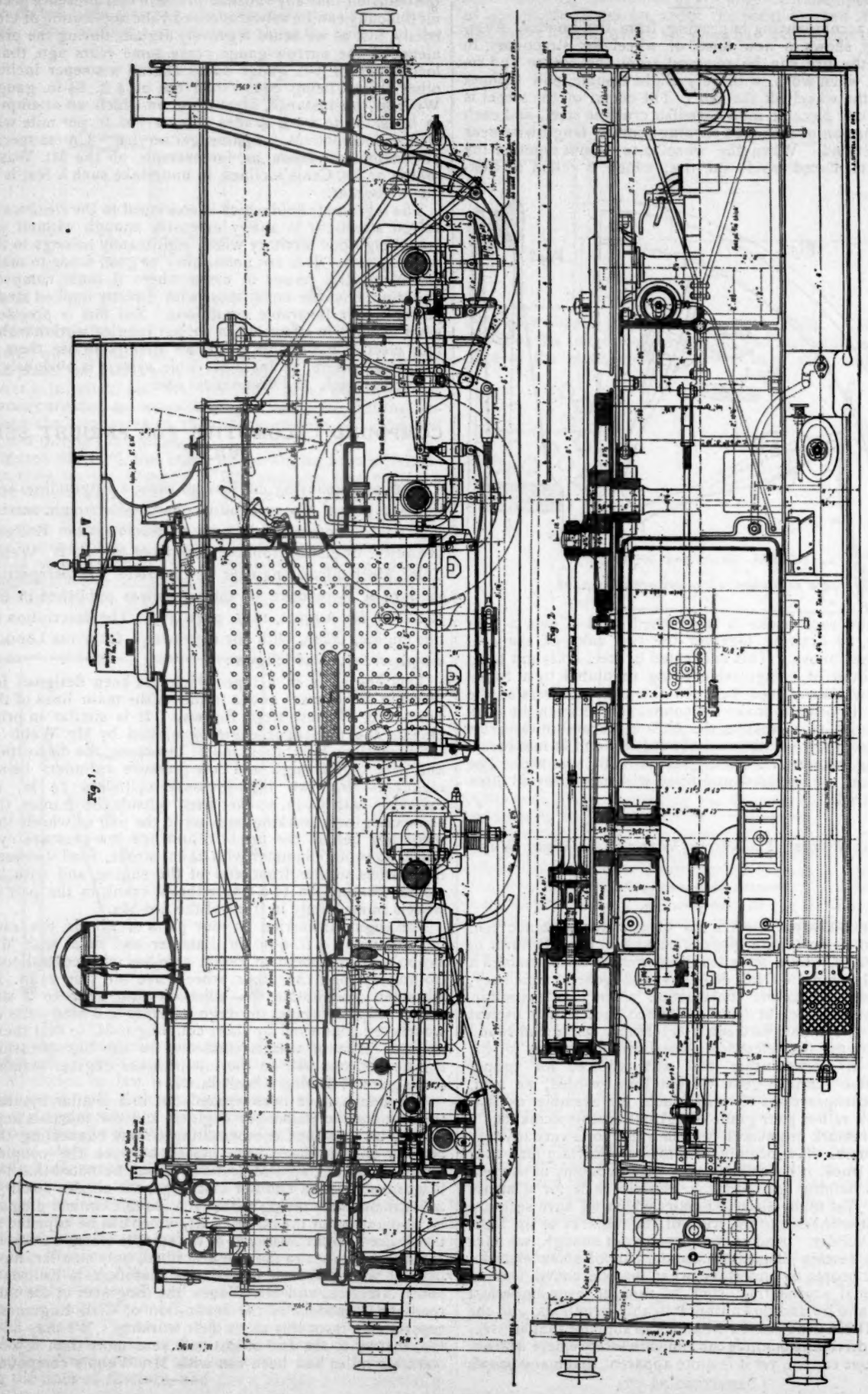
THE accompanying engravings show a longitudinal section and plan of a compound locomotive for freight service built at the shops of the London & Northwestern Railway at Crewe, England, from the designs of Mr. F. W. Webb, Chief Mechanical Engineer of that road. A perspective view of a locomotive of this class was published in the JOURNAL for August, 1887, page 363. The description of this engine, taken, with the engravings, from the London *Engineering*, is as follows:

This engine is of a type which has been designed for working the express goods traffic on the main lines of the London & Northwestern Railway. It is similar in principle to the passenger engine exhibited by Mr. Webb at the Inventions Exhibition and at Liverpool, the disposition and size of the high and low-pressure cylinders being identical—viz., two high-pressure cylinders 14 in. in diameter with 24-in. stroke, fixed outside the frames, the connecting-rods working back on to the pair of wheels immediately behind the fire-box, and one low-pressure cylinder, 30 in. in diameter with 24-in. stroke, fixed between the frames at the front end of the engine, and with its piston working on to a single-throw crank in the pair of wheels immediately in front of the fire-box.

The engine is carried on four pairs of wheels, the leading pair being 3 ft. 9 in. in diameter and fitted with Mr. Webb's arrangement of radial axle-box with central controlling spring; the other wheels are all 5 ft. 2½ in. in diameter. To obtain the adhesion equivalent to a six-wheel coupled engine, the high-pressure and hind pairs of wheels are connected by short coupling-rods, so that there are two pairs of wheels connected to the high-pressure engine and one pair to the low-pressure engine, making three pairs of driving wheels in all.

The details have been worked out in a similar manner to those for the passenger engines, and the journals kept as long as possible; compensating beams connecting the bearing springs have been placed between the coupled wheels. Among special features it may be noted that the blast nozzle has an annular discharge, the nozzle—itself 5¼ in. in diameter—having within it a double conical plug 2¾ in. in diameter at the largest part, which can be adjusted at the desired height by means of the spindle which carries it.

Similar engines to the one described, only smaller, have been at work for some time on the Antofagasta Railroad, South America, and Mr. Woods, the Engineer of the railroad and President of the Institution of Civil Engineers, reports very favorably as to their working. We may add, too, that up to the end of last half year more than 6,500,000 train-miles had been run with Mr. Webb's compound



COMPOUND LOCOMOTIVE ON WEBB'S SYSTEM, FOR FREIGHT SERVICE.

BUILT AT THE LONDON & NORTHWESTERN RAILWAY SHOPS, CREWE, ENGLAND. F. W. WEBB, CHIEF MECHANICAL ENGINEER.

engines on the London & Northwestern Railway, on which line they are now doing all the heaviest main line work and saving a large amount of double-engine running which was formerly necessary.

The following are the dimensions of the engine illustrated :

CYLINDERS AND MOTION (VALVE MOTION, JOY'S) :	Ft.	In.
High-pressure cylinders	2	
Diameter	1	2
Stroke	2	0
Length of ports	0	10
Width of steam ports	0	1⅜
" exhaust "	0	2¾
Maximum travel of valve	0	3½
Lap of valves	0	1 1/16
Lead "	0	3/16
Inside clearance	0	3/16
Distance between centers of cylinders	6	6
Low-pressure cylinder	1	
Diameter	2	6
Stroke	2	0
Length of ports	1	6
Width "	0	2
" exhaust ports	0	4¾
Maximum travel of valve	0	5
Lap of valve	0	1
Lead	0	½
Length of high-pressure connecting-rods between centers	8	3
Diameter of crank-pin bearings (high-pressure)	0	4
Length of crank-pin bearings (high-pressure)	0	5
" coupling rod	5	9
" low-pressure connecting-rod between centers	5	8
Diameter of low-pressure crank bearings	0	7¾
Length " " "	0	5½
FRAMES :		
Thickness of main frames (steel)	0	1
" inner " "	0	¾
Distance between main frames	4	2
" " inner "	2	1½
Length of engine framing over buffer plates.	31	0¼
Width over footplates	8	2
WHEELS, AXLES, AND SPRINGS :		
Diameter of leading wheels, with 3-in. tires	3	9
" low-pressure driving wheels, with 3-in. tires	5	2½
Diameter of high-pressure driving wheels (coupled), with 3-in. tires	5	2½
Distance between leading and low-pressure driving wheels	7	6
Distance between low-pressure driving wheels and high-pressure driving wheels	8	3
Distance between high-pressure coupled wheels	5	9
Total wheel base	21	6
Leading axle, diameter at center	0	5¾
" " " bearings	0	6¼
" " " wheel seats	0	7½
" " length of bearings	0	10
" " centers "	3	8½
Crank axle, diameter of bearings	0	7
" " " at wheel seats	0	8½
" " length of bearings	1	1½
" " centers "	3	2½
High-pressure driving axle and trailing axle, diameter at center	0	6½
High-pressure driving axle and trailing axle, diameter at bearings	0	7
High-pressure driving axle and trailing axle, length of bearings	0	9
High-pressure driving axle and trailing axle, centers of bearings	3	10
Leading springs, span	2	8
" " number of plates	16	
" " width	0	4½
" " thickness	0	⅝
Driving springs, low-pressure. Four spiral springs 3¾ in. in diameter, 5/16 in. square steel coiled R. H., with four internal spiral springs 2½ in. in diameter, 7/16 in. square steel coiled left hand.		
High-pressure driving and trailing springs, span	2	4
High-pressure driving and trailing springs, number of plates	15	
High-pressure driving and trailing springs, width of plates	0	4
High-pressure driving and trailing springs, thickness—top plate 7/16 in., the rest ⅝ in.		
BOILER :		
Diameter of barrel outside middle ring	4	1
Length " " "	10	1
" firebox casing	5	5
Extreme depth of firebox casing below center line of barrel	4	10¼
Thickness of barrel plates	0	0½
" fire-box tube plate (copper)	0	0⅝
" smoke-box " (steel)	0	0½
" other fire-box plates (copper)	0	0½
Number of tubes (brass)	198	
Diameter outside	0	1⅞
Length between tube plates	10	4⅛
Diameter of chimney at bottom	1	4
Height of center of barrel above rails	6	10¼
Heating surface : Tubes 1004.25 sq. ft.		
Firebox 94.6 "		
Total 1098.85 "		
Grate area 177 "		

The ratio of the grate area to the heating surface is 1 : 64.26. The usual working steam pressure is 160 lbs.

The tanks have a capacity of 1,400 gallons, and are provided with a pick-up to take water from track-tanks while the engine is running.

The total weight of the engine empty is 43½ tons.

Bernardo's Method of Electric Welding.

(Dr. R. Ruhlmann in the London *Electrician*.)

WHEN the author first saw Dr. Bernardo's method in use at St. Petersburg he was involuntarily reminded of Columbus and the egg. It has been well known for many years that almost all substances were fusible in the electric arc, and Siemens, Wallner, Cowles, and others have done much work in the direction of electrical welding by this means, with more or less success.

The principal point in which Bernardo differs from his predecessors is that he makes the metal to be welded *itself the negative pole*, the positive being a carbon rod.

The strong reducing action thus brought to bear on the metal keeps it perfectly clean and unoxidized. If the poles are reversed the fluid metal is promptly covered with a layer of oxide which makes the welding almost impossible, and there is great danger of burning holes.

Bernardo uses as a source of current seven sets of accumulators in parallel, each set 70 cells in series. These he charges while working by a shunt dynamo giving 120 amperes at 175 volts. He uses special battery plates made of lead strip, as he has found that "pasted" cells will not stand the heavy charge and discharge currents he employs. Messrs. Rothschild had great trouble at Creil from using "pasted" plates.

The E. M. F. and current required depend on the size, etc., of the work to be done. As an example, to weld together two pieces of ⅜-in. boiler plate, 40 cells in series and three in parallel would be taken, one end joined to the plates, and the other by a flexible lead to a 1-in. carbon rod in a portable holder.

The metal is then touched with the rod, which is immediately withdrawn from ¼ to ½ in., thus striking an arc. The metal at the point where the arc forms melts immediately, like so much wax, and runs perfectly fluid. Through the dark spectacles the arc appears like a blowpipe flame, and is manipulated much as if it were one. If

the effect is too strong, and the metal boils and evaporates, fewer cells in parallel are used; if the arc goes out too often more are added in series.

If heavy pieces of metal of high melting point are to be joined, large currents and E. M. F. must be used, the carbons being proportionately larger, and *vice versa*.

The action of the arc is, like of a blow-pipe flame, very local; only that part of the metal which requires to be melted is much heated, and the moment the arc is removed

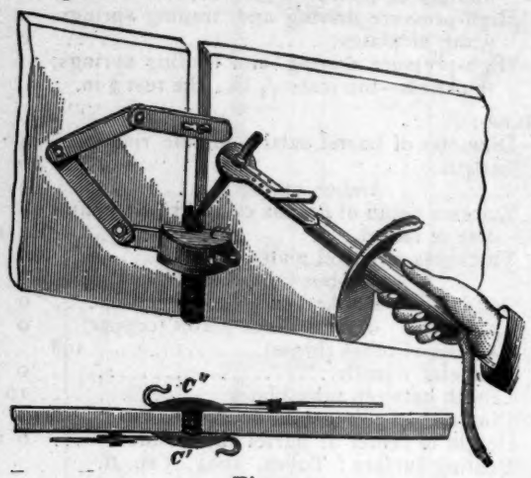


Fig. 1.

the fluid metal solidifies. The most refractory metals are instantly liquefied, and the work can be done with great rapidity.

The metals to be operated on require hardly any previous preparation, as with the high E. M. F. and currents used even a heavy coating of rust is at once fused. A little sand is used to unite with any oxide not reduced, and the slag thus formed protects the finished part from the oxygen of the air while cooling.

It is a great advantage in Bernardo's method over ordinary welding that the heat can be so easily taken to the place required, instead of having to bring the metal to the forge. In repairing a boiler, for instance, there is a good example of the extreme simplicity and convenience of the method. The negative lead is attached to any part

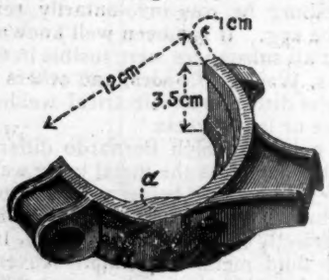


Fig. 2.

of the boiler by a small vice on the left hand, and then by taking the positive carbon-holder in the hand any part of the boiler can be operated on.

Besides welding two pieces of steel, wrought or cast iron, etc., together, the process has been used to join with

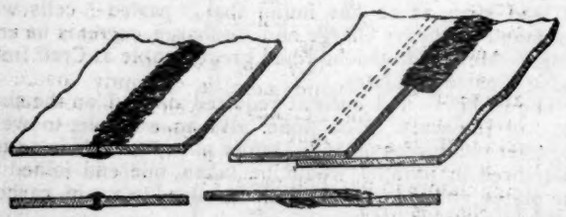


Fig. 3. Fig. 4.

copper, tin, zinc, brass, lead, steel, or cast iron, as also to weld copper and brass, brass and brass, etc., and to coat iron with copper, tin, and lead. It may also be used to cut up as well as join a piece of iron plate, etc., as the metal runs off like water if no means are taken to retain it; and it may be noted that the process may even be used *under water* both for welding and for cutting metals.

Since the action is so rapid, and the metal so quickly cooled after welding by conduction to the surrounding

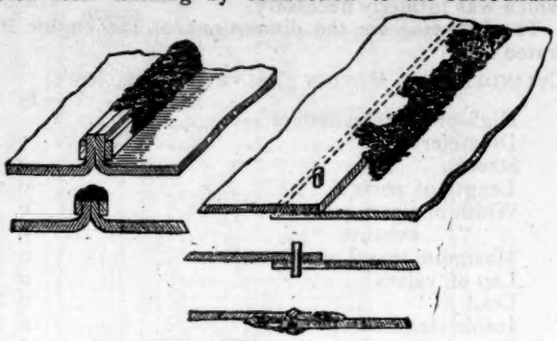


Fig. 5.

parts, there is no time for any appreciable chemical action to take place, as the following analysis shows:

Analysis.	Steel.		Iron.	
	Unworked.	Melted.	Unworked.	Melted.
Iron	98.86	99.39	98.90	99.43
Carbon	.48	.25	.34	.14
Silicium	.04	trace.	trace.	trace.
Manganese	.50	.25	.50	.23
Sulphur	.04	.04	.14	.09
Phosphorus	.08	.07	.12	.11
	100.00	100.00	100.00	100.00

The "melted" columns are analyses of pieces obtained by allowing the fluid metal to run off under the arc instead of retaining it in place. A further advantage of joining metals electrically is that nothing of the nature of a solder

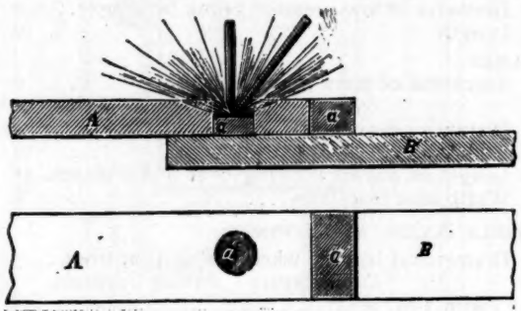


Fig. 6.

with different chemical and physical properties to the metals treated is employed, and that the joint is extremely little, if at all, weaker than the original metal.

Fig. 1 shows the method used for joining two upright

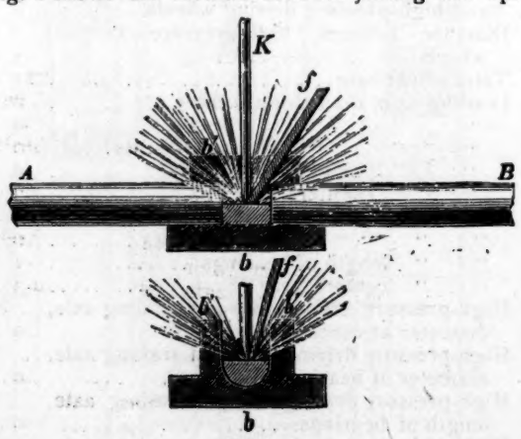


Fig. 7.

plates. C' C'' are carbon blocks to keep the fluid metal in, and are shifted up from time to time as the joint is made.

Fig. 2 is a cast-iron eccentric strap, which was broken with a hammer at *a*, and then mended by fusing it together

with small pieces of rolled iron, a little sand being used as flux. In this figure the dimensions are given in centimeters. In this case the joint is perfect, and neither hard nor brittle.

Figs. 3 and 4 show butt and lap joints, and fig. 5 a pair of plates in process of being electrically riveted. Fig. 6 shows what may be called a "semi-riveted" joint. The upper plate only is punched, and a sort of rivet of molten metal built up in the hole, the edge of the upper plate being welded on the lower in addition. In this figure a piece of iron is shown which is being fused down to fill up the gap.

Fig. 7 shows two pieces of a thick iron rod being joined, a carbon block being used to retain the molten metal. In this figure also *f* shows a piece of iron being fused down to fill the space.

Among other uses may be mentioned that of welding fine steel on to a cast-iron body for tools, etc., without any risk of the steel being burned, and for filling up blow-holes which may only have been discovered after a considerable amount of work has been done on a piece of metal.

UNITED STATES NAVAL PROGRESS.

AN important bill has been introduced in Congress by Mr. W. C. Whitthorne, of Tennessee, and referred to the Naval Committee. The bill has been carefully prepared, and is said to have such strong influences in its favor that the probabilities are that it will be reported and pass with but little amendment. It is of so much importance that we give it below in full.

THE NAVAL RESERVE.

Sec. 1. It shall and may be lawful in the enrollment of the militia of the several States and Territories bordering on the sea and lake coasts, or navigable rivers, to separately form and designate as the Naval Militia, between the ages of 18 and 45, all seafaring men of whatever calling or occupation, and all men engaged in the navigation of the rivers, lakes, and other waters, all persons engaged in the construction and management of ships and craft, or any part thereof, upon such waters, together with shipowners and their employés, yacht owners, members of yacht clubs and all other associations for aquatic pursuits, and all ex-officers and enlisted men in the Navy.

Sec. 2. The several States and Territories, having enrolled under sec. 1 a naval militia, shall be authorized to organize under their militia laws from persons composing the naval militia and others such commands as may volunteer to form portions of the following naval reserve forces: First, a Naval Reserve Artillery; second, a Naval Reserve Torpedo Corps. When so organized and reported by the governors of the States or Territories to the Navy Department, the Secretary of the Navy shall be authorized to supply arms and equipments, and naval vessels when it can be done without injury to the service, for instruction and drill.

Sec. 3. That the battery, to consist of not less than four officers and 80 petty officers and men, shall be the unit of the Naval Reserve Artillery, and that the crew, to consist of not less than one officer and 16 petty officers and men, shall be the unit of the Naval Reserve Torpedo Corps, and that the further organization, the officering, equipment and uniform of the above forces shall be prescribed by regulations established by the President, provided that the officers shall be selected and commissioned by the State authorities, and that if found qualified by a board of naval officers, appointed by the Secretary of the Navy, they may be commissioned by the President in the same titles and grades; and provided further, that the holders of such commissions shall have no claim upon the United States for compensation except when called into service by the President for war or training purposes.

Sec. 4. That the Naval Reserve forces may be called into the service of the United States under the following circumstances, and with the following conditions: First, in all cases where existing laws authorize the President to call out the militia; second, for a period of annual drill at such places as the President may designate, not to exceed one month; third, when so called into the service of the United States, the officers and men of the Naval Reserve forces will receive transportation from and to their homes, and pay and allowances similar to those allotted to the same grades and ratings in the regular naval service; fourth, it shall be the duty of the Secretary of the Navy to prescribe general regulations for the execution of the above article and the other provisions of this act.

Sec. 5. That annual mileage compensation, based on tonnage, speed, and steaming distance, shall be paid to the owners of such steam vessels now built and pronounced suitable for auxiliary cruisers by a board of naval officers appointed by the Secretary of the Navy, or which may hereafter be constructed in accordance with the requirement of the Secretary of the Navy; provided, that such vessels shall be engaged in the lake, coasting, or foreign trade, and shall sail under the flag of the United States; and provided, further, that to entitle such a vessel to the annual mileage, one-half her crew, exclusive of stewards, cooks, and servants, must be American citizens.

Sec. 6. That steamers so selected or constructed shall be built of iron or of steel, shall be capable of mounting not less than two high-powered rifles of a minimum caliber of 5 in., shall satisfy the requirements of the Navy Department as to speed, capacity for protection, coal endurance, and general fitness, which requirements may be modified from time to time, and shall be borne upon the navy register as first or second-class auxiliary cruisers.

Sec. 7. That the amount of the annual mileage paid for a steamer under the provisions of this act shall be determined by a board, consisting of three representatives of the shipping interests and three naval officers, and may be modified from time to time, subject to the approval of the Secretary of the Navy; provided, that the maximum mileage for any vessel in the foreign trade shall not exceed 30 cents per ton of net tonnage per 1,000 miles, and that the maximum mileage for any vessel in the coasting trade shall not exceed 20 cents per ton of net tonnage per 1,000 miles, and that the maximum mileage for any vessel in the lake trade shall not exceed — cents per ton of net tonnage per 1,000 miles; and provided, that no mileage shall be paid for any vessel in the foreign, coasting, or lake trade whose sea speed for 24 hours is less than 14 knots; and provided, further, that the maximum mileage shall not be paid for any vessel whose sea speed for 24 hours is less than 18 knots.

Sec. 8. That the United States shall have the right to take any vessel for which an annual mileage is paid for temporary or permanent use in time of actual war, or when an outbreak of war is imminent, and that the Secretary of the Navy shall agree upon the terms of charter or purchase with the owners, and shall execute a provisional contract with them to this effect for a stated term of years, which contract shall be renewed from time to time, and shall contain a provision forbidding sale or charter to a foreign flag without the consent of the Secretary of the Navy; provided, that no mileage shall be paid for a ship unless such a contract has been in force during the time for which the mileage is paid; and provided, further, that the owners of a vessel for which mileage is paid shall be held in bonds of —— for a faithful performance of their contract.

Sec. 9. That the officers and men between the ages of 18 and 40, serving in yachts and merchant vessels of the United States, and who are citizens of the United States, who shall so elect, and who shall be found physically and professionally qualified by a board of naval officers appointed by the Secretary of the Navy, shall be enrolled in a naval reserve, for periods not exceeding five years, in grades and ratings for which they may be found qualified, and which shall be established by the President, corresponding to grades and rating existing in the Navy; provided, that such officers and men shall be held to be in the United States service during such period of enrollment, and may be called into active service in time of actual war, or when the danger of war is imminent, and shall obey such call under the pains and penalty of desertion; provided, further, that whenever the owner, officers, and seamen of a yacht propose to enroll themselves and vessel as a part of the auxiliary navy of the United States, with-

out cost to the Government, and the said vessel shall be approved by the Secretary of the Navy as fit for dispatch, torpedo, or other auxiliary naval service, he is authorized to enroll the same; and provided, further, that the officers and men of the life-saving service, the light-house service, the revenue marine, and the coast signal service may be enrolled in the naval reserves, and may be assigned to such duties and receive such annual instruction in naval warfare as the President may prescribe.

Sec. 10. That each officer and man of the navigating naval reserves shall be required to report in person once each year to such naval authority as the Secretary of the Navy may select, and shall satisfy such inquiries and examinations prescribed by the Navy Department as may be necessary to ascertain his continued fitness for duty; and upon the completion of this annual requirement each officer shall receive $50, each petty officer $25, and each man of inferior rating $20; provided, that no annual premium shall be paid except when this report in person is made; and that if the examination shows unfitness for duty in the grades of rating held by any navigating naval reserve officer or man, he shall be at once discharged from the service without further compensation.

Sec. 11. That the navigating naval reserves shall not be called into active service in time of peace, but such officers and men of this branch as may elect to join the colors for naval training during the period of annual drill of the organized reserve forces shall be mustered into the naval service of the United States for that period, and shall receive the same pay and allowances as the organized reserve forces.

Sec. 12. That a yacht commanded by an officer of the naval reserves, or a merchant vessel so commanded, and which shall have in her complement five other officers and men belonging to the naval reserves, shall have the right to fly from her mainmast head a burgee with the letters "U. S. N. R.," provided, that the color, shape, and size of such burgees shall be prescribed by the Secretary of the Navy, and that the burgees shall be furnished by the Navy Department.

Sec. 13. That all officers of the naval reserves holding commissions from the United States shall be borne upon the naval register under their respective classifications—namely, naval reserve artillery, naval reserve torpedo corps, and navigating naval reserve.

Sec. 14. That the entire organization, administration, training, and control of the naval reserve forces exercised by the Government of the United States shall, under the direction of the President, be confided to the Secretary of the Navy, who is hereby authorized to detail, at the request of State authorities, officers and petty officers of the navy to act as inspectors, instructors, and assistant instructors of the naval reserve artillery and torpedo corps, and to be the responsible custodians of the property of the United States issued for the training and arming of the said forces.

Sec. 15. That, to promote seamanship, and to improve the qualifications of the navigating naval reserve, the Secretary of the Navy is hereby authorized to supply a detail of naval officers to any schoolship for training boys in seamanship and navigation which may be established by the authorities of a State; provided that all expense of purchase or hire and equipment of such schoolship shall be borne by the State establishing it; and provided, further, that no schoolship so established and officered shall be used in any sense as a reformatory institution.

Sec. 16. That all laws and sections of laws conflicting with the provisions of this act are hereby repealed.

TRIAL OF THE "CHICAGO."

Captain H. B. Robeson, who commanded the new cruiser *Chicago* on her trial trip on Long Island Sound, shortly thereafter made a report to the Navy Department. During the trial the weather was clear, with a strong breeze and moderate gales from the northward and westward. As far as observed, the force of the wind did not affect the speed, the ship having no top-hamper whatever. The sea was moderate, except in that part of the Sound to the eastward of Stratford Point, where a slight swell from the northwest was experienced. The distance run was carefully noted by bearings of objects on shore, by two patent logs and the log chip, these observations, as far as possible, being taken every half hour. These data, with an allowance for the tide, are given in a tabulated record of speed accompanying the report, showing that the distance recorded by the log was slightly below the actual distance shown by the bearings. The run was extended further to the eastward than was at first intended, owing to the temporary disability of the steering engine. One of the eccentric straps became loose, and made necessary a change from steam to hand, and as it was found desirable to make the run with the steam steerer, a slight delay occurred in the time of running. The steerer again became disabled from the same cause, and the ship was steered by hand during the last hour of the run. The six-hour trial was finished at 3.30 P.M., the ship having run 85.30 nautical miles by the chart, or, with the allowance for tides, 90.63 nautical miles. The mean speed obtained during the run was 15.1 knots, and the maximum speed for any one hour was 16.35 knots. The mean H. P. developed was 5,084, and the maximum for one hour, 5,248. The machinery worked smoothly for the entire run, and though water was occasionally used on the journals, the engines were not stopped or slowed down at any time during the trial. The engines worked quickly and efficiently, and all signals from the deck were promptly answered. During a temporary adjustment of the steam steerer the ship was easily handled in the East River by working the twin screws. No report is made of the air pressure, as it was not considered either desirable or necessary to close the fire-rooms. All the steam that could be worked through the engines was furnished by the blower assisting the natural draught. Chief Engineer Henderson reported that the ability of the fire-rooms to maintain the air pressure required by contract was proved by tests at Chester.

The ship steers well, and when the steering engine is properly adjusted and a few minor defects corrected the steam steerer will give satisfactory results. The steam capstan did not work well, and much difficulty was experienced in weighing the anchor. The reversing gear of the anchor engine does not work at all, and its present condition is useless. Captain Robeson says that some arrangement should be also made to keep the chain on a level with the barrel of the capstan. The pawls on the gun-deck capstan were all broken, and should be replaced with pawls of wrought iron. Owing to the horizontal position of the anchor engine attached to the lower side of the main deck the vibrations in working the engine are excessive. The steam trial clearly showed the necessity of making different arrangements regarding the fire-room hatches. It is probable that the maximum speed corresponding to the developed H.P. was not made on this trial because of the foul condition of the vessel's bottom.

The *Chicago* has two compound engines with cylinders 45 in. and 78 in. diameter and 57¾-in. stroke. The engines differ from those of the other new cruisers; they are of the beam pattern, the cylinders being vertical and the connecting rods coupled to overhead walking-beams. This design was presented by the civilian members of the Advisory Board, which adopted the plans.

The boilers are also somewhat peculiar in design; they are fired from their lower exterior surface, the furnaces being entirely outside. These furnaces are of firebrick in a wrought-iron casing. There are six boilers to supply the main engines, with two for the auxiliary engines.

On the trial the mean pressure carried, with natural draft, was about 87 lbs. on the main boilers.

Quadruple-Expansion Marine Engines.

(From the London *Engineering*.)

QUADRUPLE-EXPANSION engines of the type patented by Mr. Walter Brock, of the firm of Denny & Co., Dumbarton, and of which a brief notice was given in a late issue of *Engineering*, have recently been brought into use on the screw steamer *Kron Prinz Friedrich-Wilhelm*, one of the large fleet owned by the North German Lloyd Company. The new cylinders, boilers, etc., were made in Dumbarton by the firm just mentioned, and shipped to Bremerhaven, where they were fitted to the old engines by the workmen of the owners; and the time for completing

the work, and the high style and finish, reflect the greatest credit on the engineering staff of the Norddeutscher Lloyd Company. Messrs. Boénig and Knafft, the company's superintendents, had the work of conversion under their special supervision; and Mr. Stirling represented the Dumbarton engineering firm.

The dimensions of the steamer are: Length, 318 ft.; breadth of beam, 39 ft. 6 in.; depth, 31 ft. Prior to her conversion she had a pair of engines constructed on the old system, the cylinders being 48 in. and 88 in. in diameter, with piston stroke of 48 in.; and the steam that was supplied to them was of 60 lbs. pressure, and generated in four single-ended boilers.

In their converted form the engines have cylinders of 21½ in., 30½ in., 43 in., and 61 in. in diameter, respectively, with piston stroke the same as formerly. They are supplied with steam of 170 lbs. pressure from two double-ended boilers, which have a heating surface of 4,338 square feet, and a grate surface of 173 square feet. In the engine-room there are placed two of Messrs. Weir's patent pumps, and the distiller and feed-heater of the same firm. The patent combined steam and hydraulic starting gear of Messrs. Brown Brothers, Edinburgh, is also supplied. The circulating pump in the old engines has been done away with, and its place is filled by one of Messrs. Gwynne's patent centrifugal pumps.

The trials of the steamer with her converted engines took place on the Weser in the early part of last month, when results were obtained which cannot but be regarded as highly satisfactory. Tested on the measured mile, and between the lights, the *Kron Prinz* maintained a mean speed for six hours of 13.19 knots, which is a considerable increase over her previous performances. At the same time trials were made of the consumption of fuel, the results of which thoroughly satisfied the representatives of the Norddeutscher Lloyd Company. During the trials the engines indicated about 1,700 H. P. In consequence of the greatly increased economy of the engines now in use on board the *Kron Prinz*, the owners have been enabled to convert a considerable portion of the coal bunkers into cargo-carrying space.

When taken in conjunction with the results of the trials lately made with the steamer *Tenasserim* on the Clyde, the results obtained with the *Kron Prinz* abundantly show that shipowners have now placed before them an economical and efficient mode of making vessels—possibly not old in years, but behind date in their machinery—able to hold their own with their more modern competitors. There is likewise the important fact that Messrs. Denny & Co. have a considerable number of vessels in hand for the conversion of their engines in the same way. The engineers were represented at the trials by Mr. Brock, the patentee. The *Kron Prinz* will shortly leave, if she has not already left, on a voyage to Buenos Ayres, the results of which are being looked forward to with a great degree of interest; and it is confidently anticipated that they will amply confirm the good impression formed regarding the new machinery by the owners at the trials on the Weser. The engines are under the charge of Mr. Schultze, one of the company's chief engineers.

The American Iron Trade in 1887.

(From the *Bulletin* of the American Iron and Steel Association.)

THE year which has just closed was one of great activity and fair prosperity for the iron trade of this country. Production in all leading branches of the manufacture of iron and steel was the largest in our history—larger than in the remarkable year 1886, when all previous achievements were left far behind. We estimate our production of pig iron in 1887 at 6,250,000 gross tons, or about 600,000 tons more than in 1886, when our production was 5,683,329 tons. Our production of Bessemer steel rails in 1887 was about 1,950,000 gross tons, or about 375,000 tons more than in 1886, when our production was 1,574,703 tons. In addition to our large production of pig iron in 1887 we also consumed about 500,000 tons of imported pig iron and about 160,000 tons of imported steel rails. Our imports of iron and steel in other forms in 1887 were also very large, the total importations of iron and steel in all forms aggregating nearly 1,800,000 tons. Our production of iron ore in 1887 was about 11,000,000 gross tons, and our imports in the same year amounted to about 1,250,000 tons. In 1886 we produced about 10,000,000 gross tons of iron ore and imported 1,039,433 tons.

The impetus which had been given to the domestic iron trade in the closing months of 1885 and which had been so much accelerated in 1886 that the year closed with excited markets was still further emphasized in the first six months of 1887, during which period the demand for all forms of iron and steel was active and constant. Prices of steel rails advanced during these six months, but other prices generally declined. After the middle of the year all prices fell off in sympathy with the general conviction that the remarkable activity of the preceding year and a half could not much longer be maintained, especially the phenomenal demand for steel rails for new railroads. The following table gives the monthly range of prices for eight leading products during 1887, averaged from weekly quotations.

MONTHS.	Old iron 'T' rails, at Philadelphia.	No. 1 anthracite foundry pig iron, at Philadelphia.	Gray forge pig iron, at Philadelphia.	Gray forge pig iron, Lake ore mixed, at Pittsburgh.	Steel rails, at mills in Pennsylvania.	Best refined bar iron, from store, at Philadelphia.	All muck bar iron, at Pittsburgh.	Iron nails (gross price), at Pittsburgh.
	$	$	$	$	$	cts.	cts.	$
January	25.25	21.50	18 50	20.50	38.50	2.15	2.00	2.35
February	24.00	21.50	19.00	21.00	39.50	2.25	2.00	2.60
March	23.00	21.00	19.00	20.50	39.50	2.30	2.00	2.60
April	22.75	20.75	18.50	20.25	39.25	2.30	2.00	2.35
May	21.85	20.85	18.00	19 00	39.00	2.30	2.00	2.15
June	22.60	21.00	17.85	18.50	39.00	2.20	2.00	2.05
July	23.50	21.00	17.60	18.50	38.50	2.20	1.90	2.00
August	24.00	21.00	17.25	18.50	37.00	2.20	1.90	2.00
September	22.75	21.00	17.00	18 50	36.00	2.20	1.90	2.00
October	22.00	20.50	17.00	18.25	34.25	2.15	1.90	2.00
November	22.00	20.50	17.00	17 75	32.50	2.10	1.90	1.85
December	22.00	20.50	16.75	17.00	32.50	2.10	1.85	1.90

The decline in the demand for steel rails, foreshadowed soon after the middle of the year, was clearly visible in August, more noticeable in September, and a subject of general comment and some apprehension in October. In that month the steel-rail manufacturers met at Philadelphia, and unanimous action was taken, which has since had the effect of steadying the market. Several mills were closed in December through a scarcity of orders at remunerative prices, and it is understood that some of these will remain closed and that others now running will close if the policy of leading railroad companies in withholding orders until prices can be still further reduced is not changed. Prices of steel rails fell $6 during the last six months of the year, compelling at its close a very general reduction at steel-rail mills of about 10 per cent. in wages. If still lower prices for steel rails could be accepted a further reduction in wages would become absolutely necessary.

The manufacturers of pig iron were compelled to pay high prices for Lake Superior iron ore and Connellsville coke all through the year. No. 1 specular and magnetic Bessemer ore at Cleveland ranged from $7 to $7.50 from January to December. The advance on all grades in 1887 averaged over $1 per ton as compared with 1886. Connellsville coke was advanced from $1.50 to $2 on February 1, and this price was continued until the close of the year. Concessions upon these prices are now absolutely necessary.

Notwithstanding the decline in demand and prices which has been noted, it would not be correct to assume that the new year opens with general depression in our iron and steel industries. The shrinkage in demand is most marked in steel rails, and is next most noticeable in pig iron, bar iron, and iron pipe. But the consumption of pig iron for miscellaneous purposes is still very large, and the steel-rail manufacturers know that a large quantity of steel rails will be needed in 1888 for renewals and extensions as well as for a large mileage of new road which must be built. The bridge works of the country, the foundries,

the machine shops, the car-builders and car-wheel manufacturers, the locomotive builders, and many other consumers of iron and steel are still very busy.

We do not recall one serious strike in the iron trade of this country during 1887. There was dissatisfaction with the wages paid at various places, but the difficulties were soon healed. A protracted strike of miners and coke-drawers in the Connellsville coke district in the spring and early summer seriously interfered with the supply of coke to blast furnaces, about 50 of which were banked or blown out for several weeks. In September a strike of miners occurred in the anthracite region of Eastern Pennsylvania, which has thus far only been broken in part and which has slightly interfered with the production of pig iron in the region mentioned. Wages in the iron trade were generally advanced at the beginning of the year, but with falling markets it is too much to expect that this advance can be maintained in 1888. In addition to the reduction at some steel-rail mills which has already been noted, reductions have already taken place at some blast furnaces and a few other works.

The Nordenfelt Submarine Torpedo Boat.

(From the London *Engineer*.)

THE first approach to any official trial of the Nordenfelt submarine vessel took place December 19. It was not by any means a formal official trial, but the boat has been matured to a sufficient extent to exhibit its powers and capabilities, allowance being made for want of practice. The opportunity of witnessing such a trial was seized by representatives from the Admiralty, Ordnance Committee, Royal Engineers, and the naval attachés of foreign Powers. As our readers generally are aware, the object of this boat is to approach a ship under water, so as to escape observation, and thus discharge a torpedo in such a way as to strike an enemy with certainty, and in a vital place. In her ordinary mode of progression the vessel lies very low in the water, and is much less visible than a service torpedo boat. She would approach an enemy thus till she reached a distance at which she might run in danger of being perceived, perhaps from 2,100 to 2,500 ft.; then she would close all escape for smoke and all passage for air, and sink so low that nothing remains above water but two small gloss domes fixed at the top of two cupolas. These domes are sufficiently large to contain a man's head, one in the fore part of the ship and one aft. In this position the vessel would depend on her store of steam provided for as hereafter described, and her crew on her imprisoned air. The captain takes his stand with his head in the forward dome, a position which, it is said, gives him a singularly clear view along the surface of the water at night for such distances as are not affected by limit of horizon. Close to his hand are the handles or levers for regulating the speed and the direction of the boat, also the working of the horizontal propellers employed for descending below the surface. For rising again no propeller is necessary, the system being to adjust the boat to float with the surface of a wooden deck—which has recently been added as a superstructure—nearly level with the surface of the water. As the boat eventually nears her enemy, she descends entirely under the water, so that nothing is visible except the eddies on the surface formed by the revolution of the horizontal propellers, and these would probably be seen only in smooth water. This boat, the *Nordenfelt*, is intended to carry four, possibly five, torpedoes. Obviously the discharge of these will need skill and practice in a system so nicely adjusted. Nothing has been as yet carried out in this direction. The trial with which we now deal related exclusively to the working of the boat and to the handling of it in submerging it or in bringing it to the surface. The form of the boat, which is 135 ft. long and 12 ft. in beam, is not here discussed, because it can be best seen by drawings. Captain T. Garrett, who has had considerable experience with a submarine boat of a cigar form, has found this one much more manageable.

Two trials took place in the afternoon in Southampton water near the lightship; the first consisted in running the vessel at fast speed when in the highest position—that is, with the flat deck or superstructure a few inches above the surface of the water, in which condition the displacement is 160 tons; when submerged it is 230 tons. The object was to enable those who witnessed the trial to judge how far the boat was visible and how far vulnerable in comparison with a service torpedo boat. The superstructure is, of course, not of any vital importance. Beneath it the boat is protected by a turtle-back of steel 1 in. thick, and the conning towers or cupolas by 1 in. of steel. It is intended in future vessels to increase this to 3 in. The boat thus running at high speed obviously offered a very small mark to artillery.

The boat acquitting herself well in this trial, as well as in descending below the surface and rising again, the tender, with the officials on board, moved off toward Southampton to wait for the *Nordenfelt* to attempt an approach after dark. It may be observed that there were several difficulties to be grappled with in this task—first, the tender carried only one indifferent light, and it was a good test of the finding powers of the *Nordenfelt* in its various conditions to discover and approach her; secondly, vessels were frequently passing which called for care and prudent handling of the *Nordenfelt* to avoid danger of collision; thirdly, the difficulties of manipulating the boat were for the moment increased by the recent addition of the superstructure, which altered all the levels and adjustments, which experience had taught best suited the boat in its different movements. The result of this condition of things was that considerable delay was experienced in the operations, and the spectators on the tender had a long wait of about four hours before the actual attack was achieved. The night was a very fair one for the purpose. There was a moon, but a considerable quantity of cloud. The water was calm and the night free from mist. The *Nordenfelt* approached, sinking in the water as she neared the tender, traveling submerged wholly for about 300 ft., and was not perceived until she had sounded a whistle from a position 210 ft. on the port bow of the tender. The *Nordenfelt's* rate of speed was about 3½ or 4 knots.

On the following morning the officials and other visitors went on board the *Nordenfelt* in the dock and had the various arrangements and features of the boat explained to them, and they witnessed the submersion and rising of the boat, which was repeated so as to show that it was completely under control. Altogether the trial was most successful, but there remains much to be done before the *Nordenfelt* can be brought into condition for actual service. The introduction and successful discharge of the torpedoes have to be mastered. Then great experience is needed for handling the boat below water. Not only has the speed been hitherto kept very low, but also every change in position has been slowly and carefully effected. With a cigar-shaped boat experience has shown that there is a great liability to plunge head down, which is very dangerous in water of limited depth; but the fact is that destruction, as Captain Garrett well expressed it, is always within a very limited number of feet. But the crew of a craft engaged in naval warfare has always to run risks, and the crew of the *Nordenfelt* would be very much safer than the men in an ordinary torpedo boat. The safety of this boat is mainly secured, first, by Mr. Nordenfeldt's plan of working her in a condition when the revolution of the horizontal propellers is necessary to keep her under water, so that in any stoppage or breakdown she rises at once; and secondly, by a reserve of hot water under pressure, which, if ejected by steam, gives very great power to rise, though in a condition of partly expended motive power and temporary helplessness. Altogether the physical questions involved are very interesting. To a ship attacking harbors in the future the various forms in which attack may come to her must be peculiarly interesting. From a dynamite gun, a torpedo in the shape of a huge dynamite or gelatine shell may come hurtling through the air and fall close to her. Near the surface of the water she may strike the circuit closer of a submarine mine lying near the bottom, and at any desired depth the Nordenfelt boat may approach and discharge a torpedo at her. Near a harbor, in fact, the air, the surface and the depths of the water to the bottom itself may bring surprises upon an enemy, and this from torpedo warfare alone.

CATECHISM OF THE LOCOMOTIVE.

(Revised and enlarged.)

By M. N. Forney.

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(Continued from page 42.)

CHAPTER VIII.

THE ACTION OF THE PISTON CONNECTING-ROD AND CRANK.

QUESTION 142. *What effect does the connecting-rod have on the relative movements of the piston and crank?*

Answer. The inclination of the rod, as shown by *E F* in fig. 81, to the centre line, *A B C*, of the cylinder causes the piston to move somewhat more than half its stroke while the crank is passing from 1 to 5, or during the first quarter of its revolution, and somewhat less than half its stroke during the second and third quarter, and again somewhat more during the last quarter of the revolution, or while the crank-pin is passing from 13 to 1.

QUESTION 143. *How can this effect of the inclination or "angularity," as it is called, of the connecting-rod be shown?*

Answer. It will be made apparent if we will draw a circle, *B C*, fig. 81, representing the path of the center of the crank-pin, and then divide it into 16 equal parts, 1 2, 2 3, 3 4, etc. From 1, which is the front dead-point of the crank, a distance 1 1′ will be laid off equal to the length from center to center of the journals of the connecting-rod, and from 9, the back dead-point of the crank, a distance 9 9′ is laid off also equal to the length of the connecting-rod; 1′ and 9′ then represent the positions of the center of the cross-head pin when the crank is at its dead-points and when the piston is at the ends of its stroke. As explained before, the cross-head and the piston are rigidly connected together, so that the motion of the one represents that of the other. The movement of the center of the cross-head pin may therefore be regarded as the same as that of the piston. If now, with a pair of dividers, we take a distance equal to 1′ 1, or the length of the connecting-rod, and from 5 as a center a short arc, *E*, is described so as to intersect the center-line *A B C*, the point of intersection will represent the position of the center of the cross-head pin when the crank is at 5, or when it has turned one-quarter of a whole revolution. If we subdivide the distance 1′ 9′, which represents the stroke of the piston, into two equal parts, 1′ *a* and *a* 9′, then it will be found that the distance from 1′ to *E* is somewhat more than 1′ *a*, or than half the stroke of the piston. That is, while the crank-pin has moved from 1 to 5, or turned one-quarter of a revolution, the piston has traveled a little *more* than half its stroke. When the crank-pin reaches the dead-point at 9, then the cross-head pin will be at 9′, so that while the crank has moved through the second quarter of its revolution the cross-head pin and piston have traveled a distance, *E* 9′, somewhat *less* than half the stroke, *a* 9′.

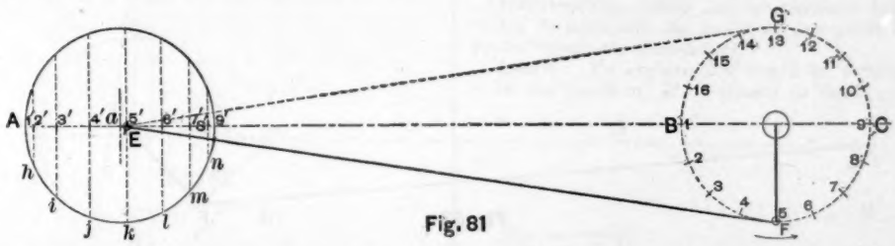


Fig. 81

Again, when the crank has reached 13, and has passed through the third quarter of its revolution, if we take the length of the connecting-rod, and from 13 as a center, with 13 *E* as a radius, describe another short arc, it will intersect *A B* again at *E*, so that while the crank-pin has revolved through the third quarter the piston has moved from 9′ to *E*, or *less* than half its stroke. When the crank again reaches 1 the cross-head pin will be at 1′, so that it and the piston have moved *more* than half a stroke while the crank passed from 13 to 1, the fourth quarter of its revolution. Owing to this *angularity*, as it is called, of the connecting-rod, the crank-pin is behind the piston during its backward stroke and ahead of it during the forward stroke.

QUESTION 144. *How does the action of the connecting-rod influence the motion of the valve in relation to the piston?*

Answer. As the crank moves slower than the piston during the first and last quarter of the revolution, and as the valve is moved by the eccentric, and it in turn by the shaft and crank, consequently the movement of the valve is delayed in relation to that of the piston during these periods. As the crank moves faster than the piston during the second and third quarters, the points of cut-off and release occur earlier in the stroke during these periods than they do during the first and fourth quarters of the crank's revolution.

This is not, however, a matter of very great practical importance with stationary engines which run at comparatively slow speeds; but if it is thought desirable, the period of admission and the point of release for both strokes can be equalized, either by giving the valve more lead or lap at one end than the other, or by making the one steam-port wider than the other. The mechanism employed for moving locomotive slide-valves, however, furnishes us with the means of modifying their motion in relation to that of the piston, and of thus equalizing the periods of admission and release for the front and back strokes. The methods of doing this will be more fully explained hereafter.

QUESTION 145. *What effect does the angularity of the connecting-rod have on the cross-head and slides?*

Answer. When the crank is revolving in the direction represented by the dart *F* in fig. 81, the connecting-rod is plainly subjected to a compressive strain while the piston is moving backward or toward the shaft, and during the first half of the revolution of the crank. The pressure on the cross-head and guides due to the angle of the rod is therefore upward. When the piston is moving from the shaft, or making its forward stroke, and the crank is passing from *C* to *B*, the connecting-rod is then in tension, and the pressure on the cross-head and guides is again upward. If, however, the crank should revolve in the opposite direction from that represented by the dart, the pressure on the cross-head and guides would be downward—that is, the direction of the pressure on the guides is reversed when the direction of the revolution of the crank is reversed, or when the engine runs backward.

QUESTION 146. *What is the nature of the motion of a piston of a steam-engine during each stroke?*

Answer. When it is at the end of the cylinder, and the crank is at one of the dead-points, the piston is momentarily at rest or stationary. After it starts its speed is increased up to a point near the middle of the stroke, where it reaches its maximum velocity. From that point the speed is diminished to the end of the stroke, when it again comes to a momentary state of rest before beginning the return stroke. During the return stroke its motion is almost exactly the same, excepting that the direction of its movement is reversed.

QUESTION 147. *How can the motion of the piston be represented graphically?*

Answer. This can be done by constructing a diagram as shown in fig. 81. In this the circle *B C*, as already explained, represents the path in which the center of the crank-pin revolves and is divided into sixteen equal parts, 1 2, 2 3, 3 4, etc. Let it be supposed that the crank is turning in the direction indicated by the arrow *F*—which is the way a locomotive driving-wheel would move in running forward. If the crank is revolving at a uniform speed the crank-pin will move through each of the spaces 1 2, 2 3, 3 4, etc., in equal times. If we take a pair of dividers, with a distance between the points equal to the length of the connecting-rod, and then with 2 as a center we describe a small arc to intersect the center line *A B* at 2′, the point of intersection will be the position of the center of the cross-head pin when the crank-pin is at 2. The distance from 1′ to 2′ will then represent the movement of the cross-head and piston while the crank-pin was passing from 1 to 2. If we place one point of the dividers at 3 and describe another arc, 3′, intersecting the center line *A B*, then the distance 2′ 3′ will be that which the cross-head has moved while the crank-pin was passing from 2 to 3. If in a similar way we draw successive arcs 4′ 5′ 6′, etc., from 4, 5, 6, etc., as centers, then the spaces 3′ 4′, 4′ 5′, 5′ 6′, etc., will represent the movement of the cross-head and piston while the crank-pin is passing over the successive spaces laid out in the circle *B C*. An inspection of the spaces 1′ 2′, 2′ 3′, 3′ 4′, etc., will show that they successively increase from the beginning to near the middle of the stroke of the piston, and they then diminish from near the middle to the end

of the stroke. The movement of the piston during its forward stroke is the same as that represented in the diagram, but in a reversed direction.

QUESTION 148. *How can the velocity of the piston during any portion of its stroke be ascertained?*

Answer. In explaining this, it will first be assumed that the stroke of the piston is 2 ft., and that the crank is moving in its path *B C* at a velocity of 30 ft. per second.

It should be noticed that a point like the center of a crank-pin which is moving in a circle is constantly changing the direction of its motion. At any one instant of time, however, it moves at right angles to the center line of the crank. Thus, when the crank *F S* is in the position shown in fig. 82, the line *a F* drawn at right angles to *F S* represents the instantaneous direction in which *F* is moving when in the position represented. If the length of *a F* represents the velocity—20 ft. per second—of the crank-pin, then by the principles of the composition of motion, if this line is made the diagonal of a parallelogram *a b F d*, of which the two sides *a b* and *d F* are horizontal and *a d* and *b F* vertical, then these sides will represent the horizontal and vertical velocity of the center of the crank-pin. As the horizontal movement of the crank-pin is nearly coincident with that of the cross-head and piston, the motion of these latter parts being communicated to the crank-pin by the connecting-rod, therefore the line *d F* or *a b*, which represent the horizontal velocity of the crank-pin, will also represent very nearly the velocity of the cross-head and piston. Similar diagrams for other positions of the crank are given in figs. 83 and 84, in which the horizontal lines *d F* represent approximately the horizontal velocity of the crank-pin and piston.

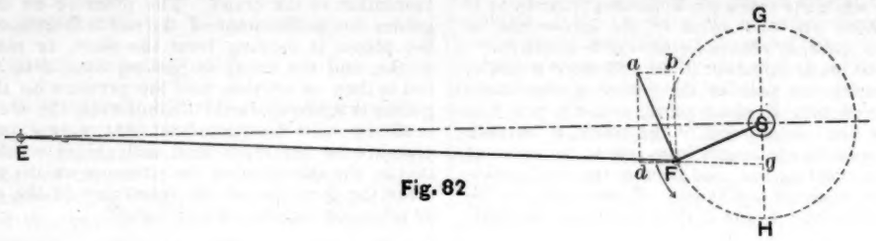


Fig. 82

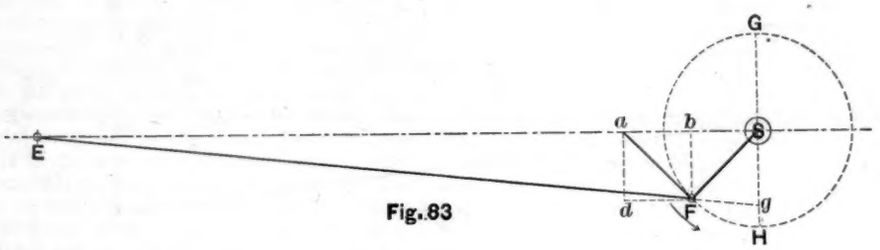


Fig. 83

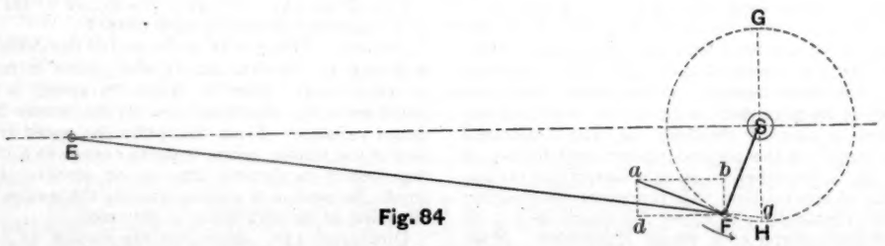


Fig. 84

QUESTION 149. *What effect has the connecting-rod on the velocity of the piston?*

Answer. As already explained, the velocity of the piston is accelerated by the connecting-rod while the former is moving from the front end of the cylinder to the middle of the stroke and again when it moves from the middle to the front end. It is correspondingly retarded at the other end of the cylinder.

QUESTION 150. *Do the diagrams in figs. 82, 83 and 84 represent the velocity of the piston precisely?*

Answer. No; they do not show the effect of the angularity of the connecting-rod.

QUESTION 151. *How can a diagram be drawn which will show the velocity of the piston correctly?*

Answer. This can be done if the line *a F*, figs. 82, 83 and 84, which represents the circumferential velocity of the crank-pin, is made equal to the radius *F S* of the crank. Then if the line *E F*, which represents the center line of the connecting-rod, is prolonged so as to intersect a vertical line *G H*, figs. 82, 83, and 84, drawn through the center of the shaft *S*, the line *g S* will represent correctly the velocity of the piston. If the crank-pin is in a position on the right side of *G H*, then the distance of *g*, the point of intersection of *E F* with the vertical line from the center, *S*, of the shaft, will represent the velocity of the piston.*

QUESTION 152. *How can the velocity of the piston be shown during its whole stroke?*

Answer. It has been explained how the velocity at any one point may be ascertained. We may determine the velocity for each of a number of successive points of the stroke, and then construct a diagram which will represent graphically the rate of speed or velocity of the piston during a whole stroke of the piston or revolution of the crank. Thus, fig. 82 represents the crank in the position marked 2 in fig. 81. The center line *E F* of the connecting-rod is extended to *g*, so that *g S* represents the velocity of the piston at the instant that the crank-pin is at 2, fig. 81. From 2′, the corresponding position of the cross-head pin, a perpendicular, 2′ *h*, is drawn downward equal to *S g* of fig. 82. In fig. 83 the crank-pin *F* is in the position 3 of fig. 81. The center line *E F* of the connecting-rod is again extended to *g*, and the distance *S g* is laid off from 3′, the corresponding position of the cross-head pin, to *i*. In the same way the velocity of the cross-head pin is plotted for each of its positions, 4′, 5′, 6′, 7′, and 8′, and a curve, *A h i j k l m n* 9′, fig. 81, is drawn through the extremities of the perpendicular lines. The perpendicular distance of this curve *below* the center line *A B* represents the velocity of the cross-head pin and piston for each point of the backward stroke. A similar curve has been drawn above the line *A B*, and shows the velocity of the piston during its forward stroke.

QUESTION 153. *What is shown by the form of these curves?*

Answer. It will be noticed that the curves are not a true circle, but somewhat egg-shaped—that is, the left-hand or front portion of each of them is fuller than at the other end, showing, as has already been pointed out, that the velocity of the piston, owing to the influence of the angularity of the connecting-rod, is somewhat greater during the first and last quarters of the revolution.

QUESTION 154. *Is any considerable amount of power required to accelerate the piston and other reciprocating parts of an engine during the first half of the stroke?*

Answer. Yes. In fast-running engines much more power is required to accelerate the reciprocating parts during the first half of each stroke than is usually supposed.

QUESTION 155. *How can this be shown?*

Answer. This will be apparent if we will compare the velocity of these parts with those of a falling body. To do this,

* The demonstration of this theorem would require the introduction of mathematical principles which would be out of place in an elementary book like this. The reader will find the whole subject very fully discussed in "A Practical Treatise on the Steam-Engine," by Arthur Rigg, and in George C. V. Holmes's excellent little book on the Steam-Engine.

it will be supposed that the cylinder of the engine is placed vertically above the crank, as shown in fig. 85, and that the cross-head starts from *A*. The curve *A h i j k l m n o* shows the velocity of the piston when the crank-pin is moving with a circumferential velocity of 30 ft. per second, which is equivalent to a speed of about 50 miles per hour for a locomotive having driving-wheels 5 ft. in diameter and 2 ft. stroke of piston. Another curve, *A n*, has been constructed to show the velocity which a body falling freely would acquire in a distance, *A g*, equal to the stroke of the piston. It should be observed that the horizontal distance of the two curves from the vertical line *A o* represents the velocities of the piston and of the falling body. They can therefore be compared with each other, and it will be seen that at the middle of the stroke of the piston its velocity is about four times that of the falling body. It must be remembered, as was explained in Chapter I, that the force which moves and gives velocity to a falling body is its own weight, or the attraction of gravitation, and that the velocity which a body acquires is proportional to the force acting on it. If, then, the reciprocating parts of an engine in moving a given

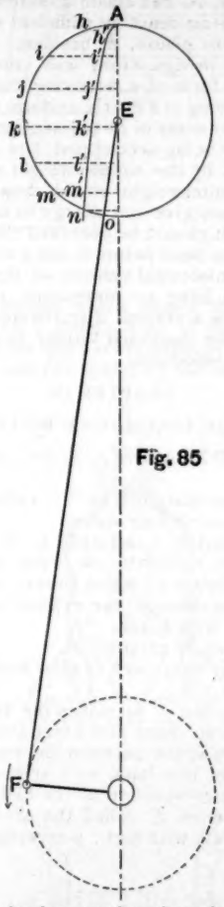


Fig. 85

distance have a velocity imparted to them four times as great as that which a falling body would acquire in the same distance, the force which acts on the reciprocating parts to produce this motion must be equal to over four times their own weight. As these parts of a passenger locomotive, with 18×24-in. cylinders, weigh about 550 lbs., the pressure on the pistons required to give them the required velocity in moving from the beginning to the middle of the stroke at a speed of 50 miles an hour must be equal to that produced by a weight of not less than 550×4=2,200 lbs. acting through a distance of one foot.

QUESTION 156. *Is the rate of the acceleration of the velocity of a piston the same as that of a falling body?*

Answer. No; a falling body can move freely under the action of the force which attracts or impels it downward, whereas the movement of the reciprocating parts of a steam-engine are restrained by the crank, which moves in its path at a nearly uniform rate of speed. The relative velocity of the piston and a falling body are shown by the form of the curves *A k o* and *A k' n* in fig. 85, from which it will be seen that in moving from *A* to *h* and *i* the rate of acceleration of the piston is very great, whereas from *i* to *j* it is very slight, and the motion begins to be retarded soon after it passes *j*. A falling body, as was explained in answer to questions 13 to 20, has a uniform increase of its velocity for every second that it falls.

QUESTION 157. *In what way can we learn how much force is required to move the reciprocating parts of an engine at the beginning of the stroke?*

Answer. This can be shown if we will imagine that the whole weight of the reciprocating parts is concentrated at the center of the crank-pin. When the crank is revolving and is at the front dead-point, as shown in fig. 86, the tendency of the weight concentrated about the center of the pin *F* would be to move in a straight line, *F w*, at right angles to the center line, *F S*, of the crank, as is shown by the way that water flies from a rapidly revolving grindstone, or sand from a carriage-wheel. This tendency to move in the direction *F w* is resisted by the crank *F S*, which, as it revolves, pulls the weight toward the center, *S*, of the shaft. This pull is called the centripetal force, which is equal to the centrifugal force, and is the same as that exerted on a string when a stone or other heavy object attached to it is whirled around. Now, if the weight was concentrated at the center of the cross-head pin *E*, fig. 81, and it was connected to the crank-pin *F* by a rod, as it is in a steam-engine, just as much force would be required to pull the weight toward the path of the crank-pin as would be needed if their weight were concentrated at *F*. Consequently, if we ascertain the centrifugal force which a weight equal to that of the reciprocating parts of an engine would exert on the crank when it is at a dead-point, we will know the force required to move these parts in a horizontal direction at the beginning of the stroke.

QUESTION 158. *How is the centrifugal force of a revolving body calculated?*

Answer. MULTIPLY THE WEIGHT OF THE REVOLVING BODY IN POUNDS, THE SQUARE OF THE NUMBER OF REVOLUTIONS PER MINUTE, THE RADIUS OR DISTANCE IN FEET FROM THE CENTER OF MOTION, AND .00034 TOGETHER, AND THE PRODUCT WILL BE THE CENTRIFUGAL FORCE.

QUESTION 159. *How can we ascertain how much force is required to accelerate the piston at any point after the crank has passed beyond the dead-point?*

Answer. To explain this it will be supposed that the crank is in the position, *F S*, shown in fig. 87. The mass, whose

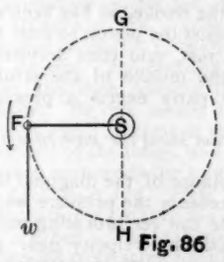


Fig. 86

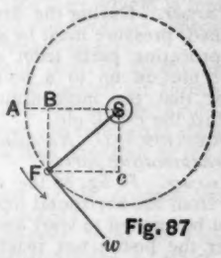


Fig. 87

weight it will again be supposed is concentrated at the center, *F*, of the crank-pin, would then, if left to itself, move in a direction, indicated by *F w*, at right angles to the crank *F S*. The centrifugal force again pulls *F* away from the center *S* and acts in the direction of *F S*. It will be plain that it is only that portion of the centrifugal force which acts horizontally that accelerates or pulls the reciprocating parts in that direction. Therefore, if *F S* is equal to the centrifugal force by drawing a parallelogram of forces, *B S c F*, with *F S* for the diagonal, and the sides *B S* and *F c* horizontal, and *B F* and *S c* perpendicular, then by the principles already explained *B S* and *F c* will represent the horizontal component or the horizontal pull exerted by the centrifugal force acting on the crank when it is in the position shown in fig. 87. Similar diagrams will show the horizontal pull of the centrifugal force for any position of the crank.*

QUESTION 160. *What would be the contrifugal force of the reciprocating parts of a locomotive which weigh 550 lbs., if it has driving-wheels 5 ft. in diameter, cylinders with 2 ft. stroke, and is running 50 miles an hour?*

Answer. By a simple calculation it will be found that at 50 miles an hour wheels 5 ft. in diameter would make 280 turns in a minute. By the rule given in answer to question 158 we would have: $550\times280^2\times1\times.00034=14{,}660$ lbs.

QUESTION 161. *How can the pressure required to accelerate the piston be shown by a diagram?*

Answer. It has been explained that the pressure required at the beginning of the stroke will be equal to the centrifugal force of the weight of the reciprocating parts, if it was concentrated at the centre of the crank-pin. Horizontal components of the centrifugal force for different positions of the crank can be ascertained by diagrams similar to fig. 87. Having done this, a line, *A E*, fig. 88, may be laid off equal to the stroke of the

* In this explanation no account has been taken of the effect of the angularity of the connecting-rod, which has some, although not a very great influence on the centrifugal action at the crank-pin.

piston, and a perpendicular, *A b*, can be drawn from the extremity *A*, whose length is equal to the centrifugal force. From *B* at a distance *A B*=to *A B*, of fig. 87, a perpendicular *B d* is drawn equal to the horizontal component, *F c*, of the centrifugal force, as shown in fig. 87. Other lines, as *C e*, may be drawn representing the action of the centrifugal force when the crank and piston are in other positions. If, now, a line, *b d e D*, is drawn through the extremities of the perpendiculars, it will be found to be a straight line, which will intersect the center *D* of the line *A E* representing the stroke; so that to make a diagram of this kind, all we need do is to calculate the centrifugal force and represent it by a perpendicular *A b* at the end of a line representing the stroke, and then draw a straight line through its extremity *b* and a point *D* in the middle of the line *A E*.

QUESTION 162. *Is the power required to accelerate the piston in moving from the beginning to the middle of the stroke lost?*

Answer. No; the power represented by the momentum of the reciprocating parts is communicated by the connecting-rod to the crank-pin after the piston has passed the middle of its stroke. It has been explained that the *horizontal* movement of the crank-pin is accelerated during the first quarter of its revolution, and is retarded during the second. Consequently, during the latter period it resists the accelerated motion or momentum of the reciprocating parts, which therefore press against it, and thus do work.

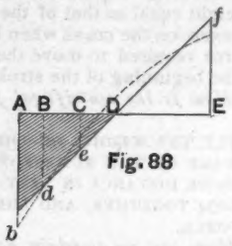


Fig. 88

QUESTION 163. *How may the effect of the momentum of the reciprocating parts be shown in the diagram?*

Answer. During the first half of the stroke, as has been explained, pressure must be exerted against the piston to start the reciprocating parts from a state of rest, and then accelerate their motion up to a point about the middle of the stroke. After that the momentum of these parts exerts a pressure against the crank-pin.

QUESTION 164. *How does the diagram show the momentum of the reciprocating parts?*

Answer. In fig. 88 the vertical distance of the diagonal line *b D* from the horizontal line *A E* represents the pressure which must be exerted to start and accelerate the reciprocating parts. After the piston has reached its maximum velocity near the middle of the stroke the motion of these parts is retarded by the crank-pin, and they consequently press against it. During the first half of the stroke these parts resist acceleration, and during the latter part they resist retardation. Or, in plainer language, in the one case they hold back, and in the other they push the crank ahead. The forces exerted during the two portions of the stroke are of opposite kinds. For that reason the force of momentum of the reciprocating parts is laid off on the opposite side of the line *A E*. As the momentum of a moving body is just equal to the force required to produce the motion, if there is no less energy from friction or other causes, the unshaded portion *D f E* of the diagram above the line *A E* represents the pressure which the reciprocating parts exert against the crank-pin, and is just equal to *b A D*. This can be proved by constructing parallelograms of force for the last half in the same way as was explained for the first half. It would thus be found that the horizontal components of the centrifugal force of the reciprocating parts in the different positions of the crank are the same for the last half as they are for the first half of the stroke, if the effect of the angularity of the connecting-rod is not taken into consideration.

QUESTION 165. *What influence does the angularity of the connecting-rod have on the pressure required to accelerate and retard the reciprocating parts?*

Answer. It has been shown from fig. 81 that the rate of acceleration of the piston during the backward stroke is greater than it is for the forward stroke, and the rate of retardation is greater for the forward stroke than for its backward movement. Consequently, if the effect of the connecting-rod is taken into account the pressure represented by *A h* in fig. 88 would be somewhat increased, and that shown by *f E* would be diminished.

The effect of the connecting-rod in thus increasing and diminishing the pressure required to accelerate and retard the reciprocating parts at the two ends of the stroke is equal to the proportion which the length of the crank bears to the connecting-rod. That is, in fig. 81 the crank is $\frac{1}{4}$ the length of the rod, so that $\frac{1}{4}$ must be added to the centrifugal force, which is equal to the pressure required to accelerate the parts when the piston is at the front end of the cylinder, and $\frac{1}{4}$ must be deducted when the piston is at the back end. The line *b D f*, fig. 88, will then be curved as shown by the dotted line.*

QUESTION 166. *What will be the effect of counterbalancing the reciprocating parts by putting a counterweight opposite to the crank?*

Answer. The effect of a counterweight can be shown if we had an engine with a double crank, as shown in fig. 89, and two cylinders, *A* and *B*, on opposite sides of the cranks. If only one of the cylinders, *A*, had steam admitted to it, obviously the pressure on the piston must be sufficient to overcome its own inertia and that of the piston, *B*, besides. If the weight of the reciprocating parts in figs. 81–84 was concentrated about the crank-pin *F*, in the form of a revolving counterweight, then if the crank was revolving at a nearly uniform velocity, the counterweight would impart some of its momentum to the reciprocating parts while they are being accelerated, and some of their energy would be absorbed by the counterweight while they are being retarded. The counterweight would thus act as a fly-wheel, and would absorb and give out energy to and from the reciprocating parts. But it should be observed that when the counterweight is passing the dead-points it has a vertical velocity equal to that of the circumferential velocity of the crank. The reciprocating parts then have no movement, consequently such a counterweight causes a vertical disturbance in the action of the engine, which will be discussed further in a chapter relating to the balancing of locomotives.

CHAPTER IX.

THE LOCOMOTIVE BOILER.

QUESTION 167. *What are the principal parts or "organs" of a locomotive boiler?*

Answer. 1. A fire-place, or, as it is called, a *fire-box*, *A* (fig. 90), which is surrounded with water.

2. A cylindrical part, *C C*, attached to the fire-box at one end and to a chamber, *B*, called the *smoke-box*, at the other.

3. The tubes or flues *a a'*, which connect the fire-box with the smoke-box and pass through the cylindrical part of the boiler and are surrounded with water.

4. The smoke-stack or chimney *D*.

QUESTION 168. *What is each of these parts or organs for, and of what do they consist?*

Answer. The fire-box *A* furnishes the room for burning the fuel, and consists of an inner and outer shell, *b* and *c*, made of boiler plate, with the space between the two filled with water; a grate, *G*, formed of iron bars, with spaces between them for admitting air for the combustion of the fuel, which is placed on the top of them; a door, *E*, called the *fire-box* or *furnace-door*, for supplying the grate with fuel; a receptacle, *E E*, below the grate, to collect ashes, and therefore called the *ash-pan*, which is supplied with suitable dampers for admitting or excluding the air from the fire.

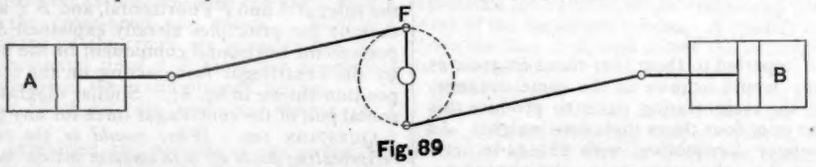


Fig. 89

The cylindrical part *C C*, or *waist* of the boiler, as it is sometimes called, contains the greater part of the water to be heated.

The smoke and products of combustion are conducted from the fire-box at the back end to the smoke-box at the front end by means of the flues or tubes, *a a'*, which are usually about 2 in. in diameter and from 10 to 12 ft. long. These tubes are surrounded with water and are made of small diameter so as to sub-divide the smoke into many small streams and thus expose it to a large radiating surface through which the heat is conducted to the water.

The chimney or smoke-stack serves partly for removing into

* The proof of this cannot be given here, but it is fully discussed in Arthur Riggs's "Practical Treatise on the Steam-Engine," in George V. Holmes's book on the same subject, and in "A Treatise on the Richards's Steam-Engine Indicator," by Charles T. Porter.

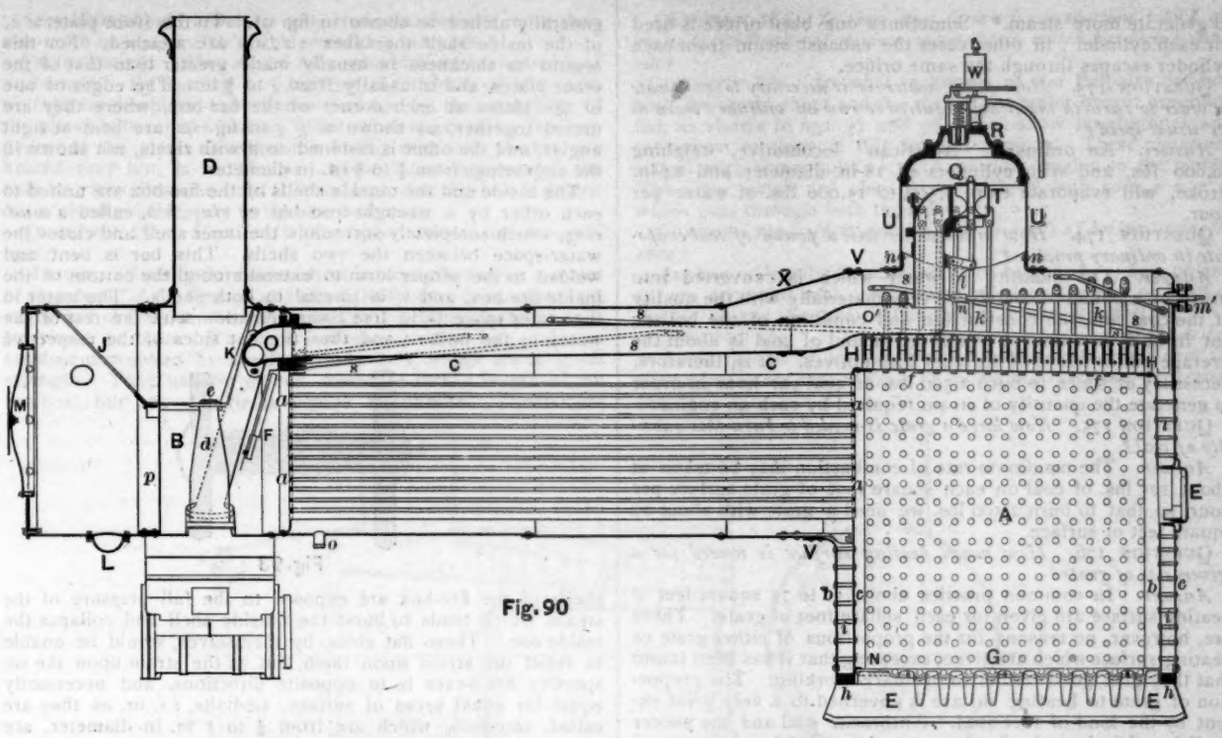


Fig. 90

the open air the smoke which passes through the flues, and partly for producing a strong draft of air, which is indispensably necessary for the rapid combustion of the fuel, and in some cases for arresting and extinguishing the sparks from the fire.

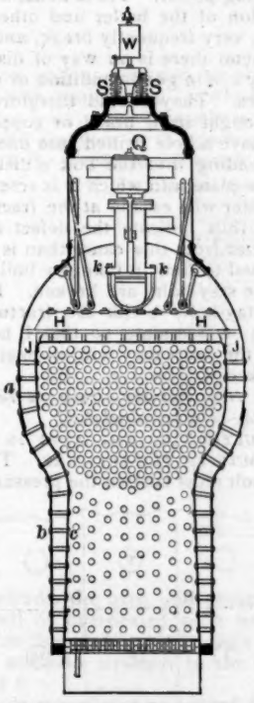


Fig. 91

QUESTION 169. *How is the draft produced in locomotive boilers?*

Answer. By conducting the exhaust steam through one or more pipes (*d*, fig. 90) from the cylinders to the smoke-box and allowing it to escape up the smoke-stack from an aperture or apertures, *f*, called an *exhaust-nozzle.* The strong current of steam thus produced in the chimney produces a vacuum in the smoke-box, by which the smoke is sucked into it with great power and forced up the chimney into the open air.

QUESTION 170. *How does the quantity of steam generated in locomotive boilers in a given time compare with that generated in the boilers of stationary and marine engines?*

Answer. Locomotive engine boilers must produce much more steam in a given time in proportion to their size than is required of the boilers of any other class of engines (excepting, perhaps, those of steam fire-engines), because the space which locomotive boilers can occupy and also their weight is limited.

QUESTION 171. *How is their steam-generating capacity increased above that of marine and stationary boilers?*

Answer. By creating a very strong draft of air through the fire and then passing the smoke and heated air through the tubes. By this means the smoke and hot air are divided into many small streams or currents, which are exposed to the inside surface of the tubes, and the heat is thus imparted to the water which surrounds the tubes.

QUESTION 172. *How is the action of the exhaust steam in producing a draft in the chimney explained?*

Answer. The exhaust steam escapes from the cylinders through contracted openings or exhaust-nozzles, *e*,* which point directly up the center of the chimney. The exhaust steam escapes from this orifice with great velocity, and expands as it rises, so that it fills the chimney *D*. It thus acts somewhat like

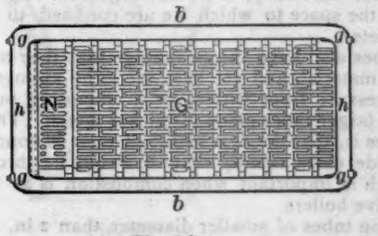


Fig. 92

a plunger or piston forced violently up the chimney, and pushes up the air above it, and, owing to the friction of the particles of air, carries that which surrounds it along with it. They finally escape into the open air, thus leaving a partial vacuum behind in the smoke-box. The external pressure of the atmosphere then forces in air through any and every opening in the smoke-box, to take the place of that already drawn out or exhausted from it. As the only inlet is through the tubes, to which the gases of combustion have free access from the fire-box, and as the external air can only pass through the fire-grate, and through the burning fuel, to reach the fire-box, there is a constant draft of air through the grate as long as the waste steam escapes from the blast-pipe and up the chimney. It is thus that, within certain limits, the more the steam that is required, the more the steam that is produced; for all the steam used in the engine draws in the air in its final escape, to excite the fire

* The term *blast-orifice* is also often used to designate these parts of locomotives.

to generate more steam.* Sometimes one blast-orifice is used for each cylinder; in other cases the exhaust steam from each cylinder escapes through the same orifice.

QUESTION 173. *How much water is it necessary to evaporate in order to furnish the steam required to run an ordinary train at its usual speed?*

Answer. An ordinary "American" locomotive, weighing 80,000 lbs. and with cylinders of 18-in. diameter and 24-in. stroke, will evaporate from 7,500 to 15,000 lbs. of water per hour.

QUESTION 174. *How much water will a pound of coal evaporate in ordinary practice?*

Answer. The quantity of water which is converted into steam by a pound of coal varies very materially with the quality of the coal and the construction and condition of the boiler; but from 6 to 8 lbs. of water per pound of coal is about the average performance of ordinary locomotives. It is, therefore, necessary at times to burn 2,500 lbs. of coal per hour in order to generate the quantity of steam required by such an engine.

QUESTION 175. *How large a grate is needed to burn this quantity of coal?*

Answer. The maximum rate of combustion may be taken at about 125 lbs. of coal on each square foot of grate surface per hour, so that to burn 2,500 lbs. we need a grate with about 20 square feet of surface.

QUESTION 176. *How much heating surface is needed for a given size of grate?*

Answer. In common practice about 50 to 75 square feet of heating surface are given for each square foot of grate. There are, however, no reasons for the proportions of either grate or heating surface which are given, excepting that it has been found that they give good results in ordinary working. The proportion of grate to heating surface is governed to a very great extent by the kind of fuel used. Anthracite coal and the poorer qualities of fuel require larger grates than good bituminous coal or wood. It is, however, quite certain that the larger a boiler is, and the greater its heating surface in proportion to the steam it must generate, other things being equal, the more economical will it be in its consumption of fuel, or, in other words, the more water will it evaporate per pound of coal.

QUESTION 177. *Why is it necessary to use small tubes or flues in order to have the required amount of heating surface?*

Answer. Because there is a great deal more surface in a small tube of a given length, in proportion to the space it occupies, than in a large one. Thus a tube 2 in. in diameter and 12 ft. long has 6.28 square feet of surface, and one 4 in. in diameter has 12.56 square inches, or just *double* the quantity. But the 4-in. tube occupies *four times* as much space as the other, as it is twice as high and twice as wide. Therefore, in proportion to the space it occupies, the tube which is 2 in. in diameter has twice as much surface as the larger one. If we compare a 2-in. with an 8-in. tube, we will find that the former has *four* times as much surface, in proportion to its size, as the 8-in. tube. As the size and weight of locomotive boilers are limited, it is therefore necessary, in order to get the requisite heating surface in the space to which we are confined, to use tubes of small diameter.

Small tubes also have the advantage that they may be made of thinner material, and yet have the same strength to resist a bursting pressure from within, or a collapsing pressure from without, as larger tubes made of thicker metal. The advantage of thin tubes is, that the heat inside of them is conducted to the water outside more rapidly than it would be through thicker metal, which is important when combustion is as rapid as it is in locomotive boilers.

The reason tubes of smaller diameter than 2 in. are not ordinarily used is because they are then liable to become stopped up with cinders and pieces of unconsumed fuel.

QUESTION 178. *How is the fire-box of a locomotive constructed?*

Answer. It usually consists of a rectangular box (*A*, figs. 90, 91, and 92) about 3 ft. wide† and, for the size of engine we have selected as an example, about 6 or 6½ ft. long inside. This box is composed of either iron or steel plates, *c c*,‡ which, excepting on the front side, are from $\frac{5}{16}$ to $\frac{3}{8}$ in. thick. It is called the *inside shell* of the fire-box, and is surrounded by an outside shell, *b b*, of either iron or steel plates, of about the same thickness as those composing the inside, and, as already explained, is so much larger than the inside that there is a space, called the *water-space*, from 2½ to 4½ in. wide, on all the sides of the fire-box between the inner and outer plates.

The top, *f f*, of the inside shell, which is called the *crown-sheet* or *crown-plate*, is usually flat, whereas the outside shell is generally arched, as shown in fig. 91. To the front plate, *a a*, of the inside shell the tubes *a a'*, *a a'* are attached. For this reason its thickness is usually made greater than that of the other plates, and is usually from $\frac{3}{8}$ to $\frac{1}{2}$ in. The edges of one of the plates at each corner of the fire-box, where they are united together, as shown at *g g* in fig. 92, are bent at right angles, and the other is fastened to it with rivets, not shown in the engraving, from $\frac{3}{8}$ to $\frac{1}{2}$ in. in diameter.

The inside and the outside shells of the fire-box are united to each other by a wrought-iron bar or *ring*, *h h*, called a *mud-ring*, which completely surrounds the inner shell and closes the water-space between the two shells. This bar is bent and welded to the proper form to extend around the bottom of the inside fire-box, and it is riveted to both shells. The water in the water-space is in free communication with the rest of the water in the boiler; and thus the flat sides of the respective

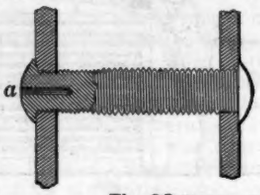


Fig. 93

shells of the fire-box are exposed to the full pressure of the steam, which tends to burst the outside shell and collapse the inside one. These flat sides, by themselves, would be unable to resist the strain upon them, but as the strain upon the respective fire-boxes is in opposite directions, and necessarily equal for equal areas of surface, tie-bolts, *i i*, or, as they are called, *stay-bolts*, which are from $\frac{3}{4}$ to 1 in. in diameter, are screwed through the plates at frequent intervals, usually from 4 to 4½ in. apart, so as to connect the inner and the outer plates of the fire-box securely together, the ends of the stay-bolts being also riveted or spread out by hammering so as still further to increase their holding power. These bolts, owing to the expansion and contraction of the boiler and other strains to which they are subjected, very frequently break, and if they are made of solid bars of metal there is no way of discovering with certainty whether they are in good condition or not without taking the boiler to pieces. They should therefore be made of the best quality of wrought iron, brass, or copper, and should be made tubular or have a hole drilled into one end, as shown at *a*, fig. 93, and extending into the bolt a distance greater than the thickness of the plate into which it is screwed, so that if the bolt breaks the water will escape at the fracture into the hole, and the leak will thus indicate the defect and danger. The latter is much greater from this cause than is usually supposed, and it is not unusual to find in taking a boiler to pieces that a large number of the stay-bolts are broken. Experience shows, too, that when stay-bolts break the fracture nearly always occurs next to the outside plate, so that if holes are drilled in the outer ends of the bolts they will, in nearly all cases, show when a bolt is broken.

QUESTION 179. *How can the strain on the flat surface of a boiler between the stay-bolts be calculated?*

Answer. BY MULTIPLYING THE AREA IN INCHES BETWEEN ADJACENT STAY-BOLTS BY THE PRESSURE. The reason for this is, that each stay-bolt must sustain the pressure on a part of the

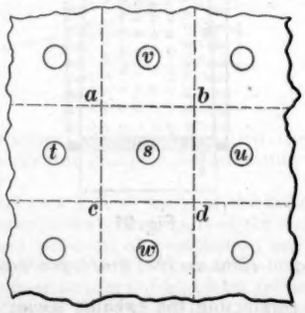


Fig. 94

plate to which it is attached. Thus in fig. 94 it is plain that the bolt *s* must sustain the pressure on one-half of that part of the plate between it and the bolts *v*, *t*, *w*, *u*, around it, or the pressure on the square *a b d c*, whose sides are equal to the distance (4 in.) between the centers of the bolts. With a pressure of 150 lbs. per square inch, the calculation would therefore be: 4×4×150=2,400 lbs. on each bolt.

* Colburn's Locomotive Engineering.

† The width is dependent upon the distance between the rails, or *gauge* of the road, as it is called. The above size is for a 4 ft. 8½ in. gauge.

‡ The inside plates are sometimes made of copper.

Stay-bolts should never be subjected to a strain of more than one-tenth or one-twelfth of their breaking strength.

QUESTION 180. *How do stay-bolts often fail without breaking?*

Answer. By tearing or *stripping* the thread of the bolt, or that in the plate, but oftener perhaps by the stretching of the plates between the holes. With a heavy pressure, the tendency of the plates between the holes, especially if they are heated very hot, is to "bulge" outward and thus stretch the hole in every direction until it is so large that the bolt is drawn out without much injury to the screw-thread.

QUESTION 181. *How is the flat-top or crown-sheet strengthened?*

Answer. Usually the crown-sheet is strengthened by a series of iron bars (*H H*, figs. 90 and 91), called *crown-bars*, placed on edge, and of considerable depth, which are firmly fastened to it by rivets or bolts. The crown-sheet can therefore only be crushed downward by bending these bars, which are of great strength. They usually extend crosswise of the length of the fire-box, but are sometimes placed lengthwise. These bars bear on the fire-box only at each end, as shown in fig. 91, and are usually made with projections, *j j*, which rest on the edges of the side plates. Iron rings or washers are interposed between the plate and the bars at the points where the bolts or rivets which secure the rivets pass through. This permits the water to circulate under the bars, and prevents the crown-sheet from being burned or overheated, as it would be if the water were excluded from the whole under surface of the crown-bars.* The crown-bars are also attached to the outer shell and the dome by *braces*, *k k*.

Crown-sheets are sometimes supported by stay-bolts, which are screwed into it and the outer shell of the boiler, as shown in figs. 95 and 96. A difficulty with this form of construction is that to resist the strains produced by the steam pressure on the crown-sheet the bolts should be placed at right angles to its surface, and to resist the pressure against the inner side of the shell of the boiler they should be radial to its cylindrical form. As it is impossible to locate them so as to be both radial to the shell and at right angles to the crown-sheet, all that can be done is to make as close an approximation to each position as is possible. Under these conditions it is difficult to know how much pressure the stay-bolts bear, and consequently the strains to which they are subjected are liable to be excessive.

* Colburn's Locomotive Engineering.

QUESTION 182. *Is there any form of construction which obviates the difficulty of staying crown-sheets which has been pointed out?*

Answer. Yes. In what is known as the Belpaire fire-box both the crown-sheet and the shell of the boiler over it are made flat, as shown in figs. 97 and 98, which show longitudinal and transverse sections of this form of fire-box. These plates are stayed with screw-bolts, *b*, *b*, *b*, at right angles to the plates. The sides, which are also flat, are stayed with rods, *r r*, *r r*, which pass through both the sides.

QUESTION 183. *How are the ends or heads of boilers strengthened?*

Answer. Usually diagonal stays or braces, *s s s*, figs. 90 and 95, are arranged with one end attached to the end or head of the boiler, and the other is fastened to its outside shell.

QUESTION 184. *What precaution should be taken in the design and construction of stays or braces like those which are used for strengthening the ends or heads of boilers and supporting the crown-bars?*

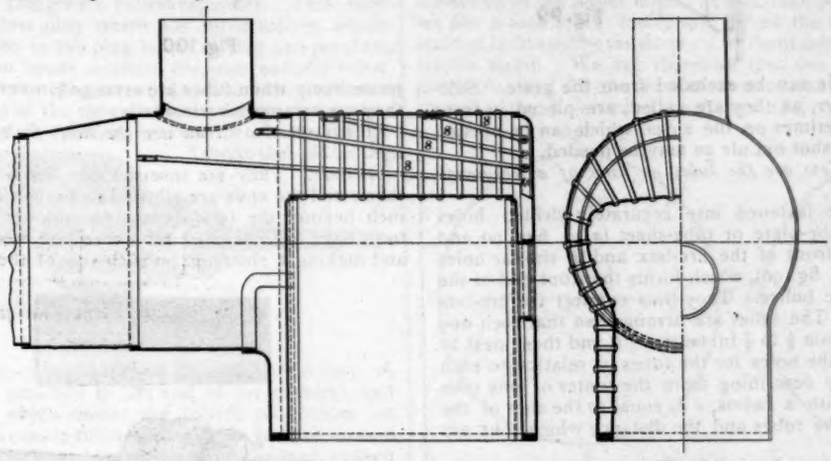


Fig. 95

Fig. 96

Answer. Great care should be taken to make the parts by which the stays are fastened as strong as the main part of the bar which forms the brace. The principle that the greatest strength of any part of a structure is only that of its weakest part applies with especial force to boiler-stays. Often the grossest carelessness and ignorance is shown in designing and constructing these parts. The eyes and the pins or keys by which they are fastened are often made so that they are much weaker than the body of the bar, and the riveted attachments to the boiler-plates often have only a small percentage of the strength of the main part of the brace or stay.

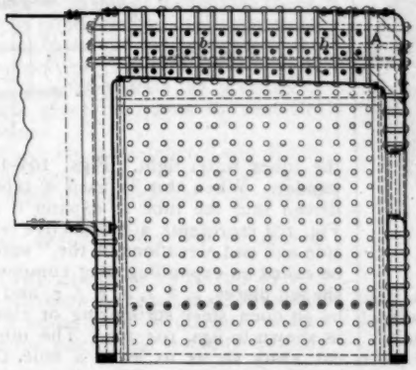


Fig. 97

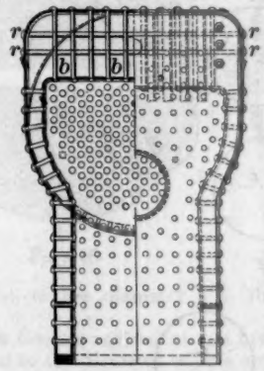


Fig. 98

QUESTION 185. *What other method of staying boiler-heads is sometimes used?*

Answer. What are called "*gusset stays*" are used a great deal in European locomotives. These consist of triangular pieces of boiler-plate *A*, figs. 99 and 100, which are fastened to the boiler-head *B* and to the shell *D* by angle-irons *C* and *C'*, which are riveted to the head and to the shell. The plate *A* is placed between the angle-irons with rivets through all three, as shown in fig. 100. Stays of this kind are often used for Belpaire fire-boxes, an example of which is shown in fig. 97.

QUESTION 186. *How are the grates constructed?*

Answer. They are generally made of cast-iron bars, and for burning coal are usually arranged so that the fire can be shaken by moving the bars. For burning anthracite coal, the grates are

sometimes made of wrought-iron tubes, through which a current of water circulates to prevent them from being overheated.

QUESTION 187. *How are cinders and burning coals which fall through the grate prevented from falling upon the road?*

Answer. By attaching a sheet-iron receptacle or ash-pan (*E E*, figs. 90 and 91), as it is called, under the grate, which is thus completely enclosed from the outside air. As it is often important when the engine is standing still to prevent any access of air to the fire-box, the ash-pan is made to fit tightly to

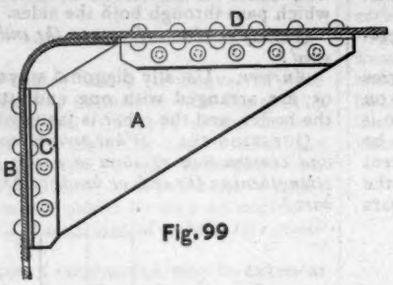


Fig. 99

the fire-box, so that air can be excluded from the grate. Suitable doors, or *dampers*, as they are called, are placed in front and behind, and sometimes on the sides, which can be opened or closed to admit or shut out air as may be needed.

QUESTION 188. *How are the tubes or flues of a locomotive arranged?*

Answer. They are fastened into accurately drilled holes in a plate called a tube-plate or tube-sheet (*a*, *a*, figs. 90 and 91), which forms the front of the fire-box and in similar holes in another plate (*a'*, *a'*, fig. 90), which forms the front end of the cylindrical part of the boiler. They thus connect the fire-box with the smoke-box. The tubes are arranged so that each one will have a space of from $\frac{1}{4}$ to $\frac{1}{2}$ in. between it and those next to it. The position of the holes for the tubes in relation to each other is determined by describing from the center of one tube (*o*, fig. 101) a circle with a radius, *o k*, equal to the sum of the outside diameter of the tubes and the distance which they are

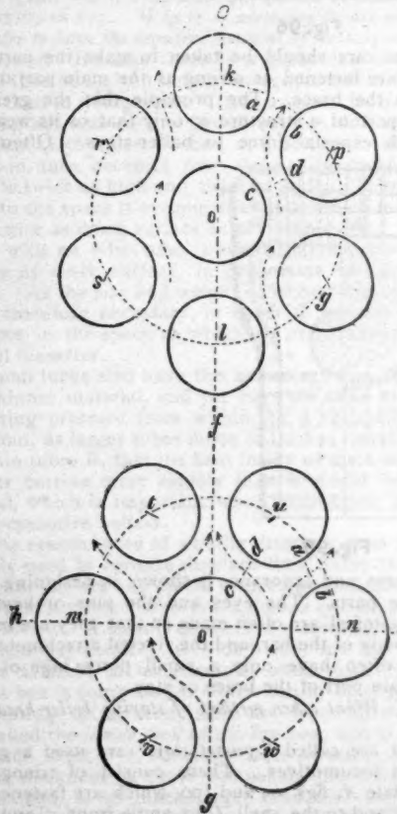


Fig. 101.

Fig. 102.

intended to be apart, and then subdividing this circle with the radius into six parts, *k r*, *r s*, *s l*, *l g*, *g p*, and *p k*. Each point of subdivision and also the center, *o*, of the circle will be the center of a tube. By laying them off from these centers it will be found that the distances *a b*, *c d* between adjoining tubes will be the same between all of them. By describing circles from the centers of the outside tubes and sub-dividing the circles as before the position of other tubes will be determined around those first laid down. This can, of course, be carried out indefinitely.

A difference in the arrangement of the tubes will be observed if, when we subdivide the first circle shown in fig. 100, instead of commencing from the intersection of a vertical line we begin from a horizontal line, *h i*, as shown in fig. 102. In the former case the tubes are said to be in *vertical rows*, and in the latter in *horizontal rows*. It is apparent from the figures and as shown by the arrows that the water can circulate in ascending currents

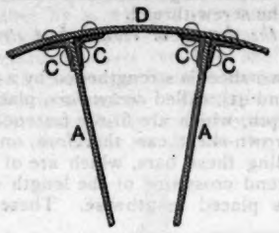


Fig. 100

more freely when tubes are arranged in vertical rows than when they are arranged horizontally.

QUESTION 189. *How are the tubes fastened and made water-tight in the tube-sheets?*

Answer. They are inserted into the holes drilled to receive them, and the ends are allowed to project about a quarter of an inch beyond the tube-sheets. A number of different kinds of tools have been devised for expanding tubes in the tube-plates and making a shoulder on each side of the plate so as to keep

Fig. 103.

Fig. 104.

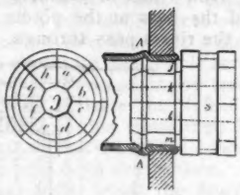


Fig. 105. Fig. 106.

the tubes water-tight. Figs. 103–107 represent Prosser's expander. When this is used a tapered plug, fig. 103, is first driven into the tube to expand it so that it will fill the hole. Fig. 104 represents a perspective view and figs 105 and 106 side and end elevations of the "spring expander." This may be called an expanding plug composed of eight or more sector-shaped pieces, *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*, which are held together by an open steel spring-ring or clasp *s*, which embraces them as shown in figs. 104–106. The inner portion of the sectors is cut away so as to leave a hole, *C*, figs. 104 and 105, in the middle of the plug. When the sections are drawn together the plug is inserted into the mouth of the tube, and a tapered plug is then driven into the hole, *C*. The spring ring or clasp *s* permits the sectors to separate when the tapered plug is driven into the opening in the center of the cluster of sectors. Each

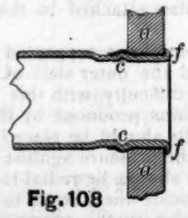


Fig. 108

of the sectors has a projection, *j*, *k*, *l*, *m*, where it comes in contact with the outer edge of the tube, and another just inside of the tube-plate. These projections form a ridge, *a b c d*, fig. 104, and another, *j k l m*, on the plug. When the tapered plug or mandrel is driven into the central opening the sectors are forced apart, and they thus expand the tube and at the same time

their projections form a ridge in the tube around the inner and outer edges of the hole in the plate, as shown at *c c*, fig. 108. By slightly turning the expander each time the mandrel is driven in, and repeating the process, the tubes can be made perfectly water-tight. In many cases, after the tubes are expanded with the tool described, the outer edge is turned over still more with what is called a *thumb-tool*, fig. 109, probably from its resemblance in form to a man's thumb. By placing the curved shoulder *a* on the end *f*, fig. 108, of the tube it is turned over, somewhat in the form shown in the engraving, by repeated blows of a hammer on the end of the tool.

Fig. 109.

Fig. 110 represents Dudgeon's roller expander. This may be described as a hollow plug which has three rollers, which are contained in cavities in the plug in which they can revolve, and in which can also move a short distance radially—that is, from the center of the plug outward. When the expander is inserted into the end of the tube a tapered mandrel, fig. 110, is driven into the central opening, and it then bears against

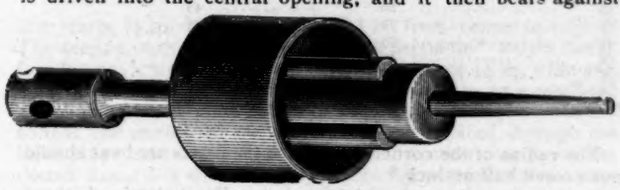


Fig. 110.

the rollers and forces them outward against the tubes. A crank handle is then attached to the end of the mandrel, and it is turned around, which causes the rollers to revolve on their own axes. This causes the hollow plug to revolve around its' axis. The two thus have a sort of sun and planet motion in relation to each other. As the rollers bear hard against the tube, the effect is to elongate it circumferentially, and thus enlarge it so as to completely fill the opening in the tube-plate.

There are other forms of tube-expanders, but those described are more generally used than any others.

Copper ferrules, represented by the black shading, *a a*, fig. 108, are also much used now on the outside of locomotive tubes, and it is said that with them the joints can be kept tight much easier than without. By turning over the outside edge of the tube, as shown in fig. 108, it not only protects the copper ferrule, but, as the tubes must act as braces to sustain the pressure of steam in the flat tube-sheets, it gives the joints the requisite strength for resisting such strains.

Cast-iron or steel ferrules, which are made tapered and drive into the mouths of the tubes, as shown in fig. 113, are also used in some cases. These are simply driven into the tube after it has been expanded.

QUESTION 190. *How can the strain on the cylindrical part of a boiler be calculated?*

Answer. BY MULTIPLYING THE DIAMETER IN INCHES BY THE LENGTH IN INCHES AND THE PRODUCT BY THE STEAM PRESSURE PER SQUARE INCH. Thus for a boiler 48 in. in diameter and 10 ft. long with 100 lbs. pressure the calculation would be $48 \times 120 \times 100 = 576{,}000$ lbs.

QUESTION 191. *Why do we multiply the diameter, instead of the circumference, by the length, to get the strain on the cylindrical part?*

Fig. 113

Answer. The reason for multiplying by the diameter instead of by the circumference is because only a portion of the pressure on the inside surface of the boiler exerts a force to burst the shell at any one point. Thus, supposing the diagram, fig. 114, to represent a section of a boiler, if we have a force acting on the shell in the direction of the line *a b*, at the point *b*, where it is exerted against the shell of the boiler, it would be composed of two forces, one acting in the direction *b e*, and tending to tear the boiler apart on the line *c d*, and the other acting in the direction *f b*, to tear it apart on the line *h g*. It is so with all pressure inside the boiler, excepting that, say *a h*, which acts exactly at right angles to the line of rupture *c d*; it is all composed of two forces, only one of which tends to tear the boiler apart at one point. It is therefore only a part of the pressure on the circumference which tends to burst the boiler at a given place, and that part is equivalent to the pressure on a surface whose width is equal to the diameter and not the circumference.

This may be difficult for those to understand who are not familiar with the principles of what is called the "resolution of forces," which were explained in Chapter VII; but it may be made clear in another way.

Let it be supposed that we have a boiler, *a b*, fig. 115, made in two halves and bolted together at *a* and *b* by flanges. It is evident that if we brought a pressure against the inside of the flanges in the direction of the darts *c* and *d*, such a pressure would not have a tendency to tear apart the bolts *a* and *b*, by which the two halves of the boiler are fastened together. Some distortion of the boiler might, in fact, take place if, for example, we put a jack-screw inside and forced the flanges *a* and *b* outward as indicated by the darts, *c d*, without subjecting the bolts to a tensile strain. We see therefore that the forces acting in the direction *c* and *d* have no tendency to tear the bolts at *a* and *b* asunder, but it is only such forces as *e*, *f*, and *g*, which act at

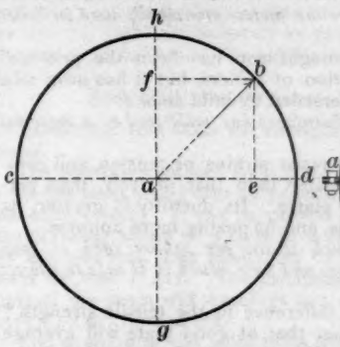


Fig. 114

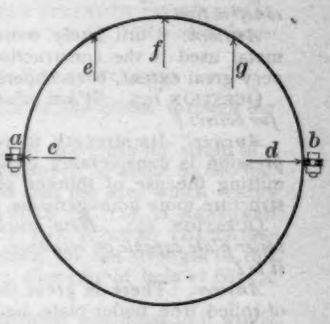


Fig. 115

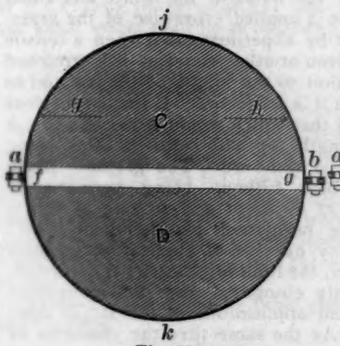


Fig. 116

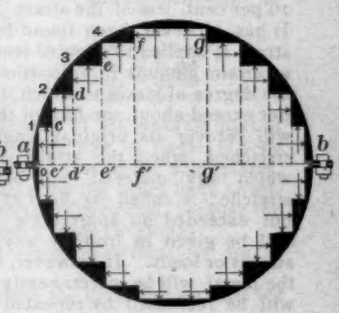


Fig. 117

right angles to the diameter *a b*, that exert a strain on the flanges.

That this force is equivalent to a pressure on a surface with a width equal to the diameter will be apparent if we suppose that we have a boiler, *a b*, fig. 116, and that each half, *C* and *D*, is nearly filled with some substance, say wood or cement, which is fitted so tight that no steam can get between it and the shell of the boiler. It will be apparent that if we admit steam into the space *f g*, the force exerted on the bolts *a* and *b* is that due to the pressure on the surface of the wood or cement exposed to the steam whose width is equal to the diameter of the boiler. It may be said, though, that if this substance were elastic, like india-rubber, the effect of the steam would be different.

But even if it were elastic, the pressure of the steam would be exerted at right angles to the surfaces *f g*, and the pressure on these surfaces would not be increased or diminished if the elastic substance should spread laterally. If it should do so and thus produce pressures in the direction *g* or *h* it would not produce any strain on the bolts *a* and *b*, to tear them apart, but such pressures would have a tendency to rupture the boiler on the line *j k*.

The effect of internal pressure in a boiler may be made clear in still another way. Let it be supposed that we have a cast-iron boiler the inside surface of which is formed as shown in fig. 117—that is, it is serrated or formed like steps, with vertical and horizontal surfaces as shown. It may be assumed, without

leading us into error, that the pressure of the steam is exerted at right angles to these surfaces—that is, that it acts in the direction indicated by the darts. Obviously the pressure which tends to pull apart the bolts *a* and *b* is that represented by the vertical darts, and which acts on the horizontal surfaces, and the total strain which these bolts must resist is equal to the area of these surfaces multiplied by the pressure per square inch. But if we draw vertical lines *c c'*, *d d'*, *e e'*, etc., from the stepped surfaces to the diameter *a b*, it will be apparent that the area of the horizontal stepped surfaces 1 *c*, 2 *d*, 3 *e*, 4 *f*. *f g*, etc., are equal to *o c'*, *c' d'*, *d' e'*, *e' f'*, *f' g'*, etc., and that they are equal in length to the diameter *a b*, so that if we multiply this diameter by the length of the boiler and the pressure per square inch it will give the pressure which is exerted on the horizontal surfaces 1 *c*, 2 *d*, 3 *e*, etc. It may now be imagined that the steps are infinitely small. In that case the internal stepped or notched surface would coincide and be equivalent to a cylinder without such notches. Therefore the reasoning which applies to the one will apply to the other. The effect of the pressure which acts horizontally or in any other direction can be shown in the same way.

The sides of a boiler must therefore be made strong enough to resist the pressure which the steam exerts on a surface the length of which is equal to that of the boiler, and the width equal to its diameter.

QUESTION 192. *What are the metals principally used in boiler construction?*

Answer. Until lately wrought iron has been the principal metal used in the construction of boilers, but it has now, to a very great extent, been superseded by mild steel.

QUESTION 193. *What advantages has mild steel as a material for boilers?*

Answer. Its strength to resist strains of tension and compression is considerably greater than that of iron, thus permitting the use of thinner plates. Its ductility is greater, its structure more homogeneous, and its quality more uniform.

QUESTION 194. *How much strain per square inch is good boiler-plate capable of resisting, and how much is it safe to subject it to?*

Answer. There is great difference in the tensile strength * of rolled iron boiler-plate, but that of good plate will average about 50,000 lbs. per square inch, if the strain is applied in the direction of the "grain" or the fibers of the iron,† and about 10 per cent. less if the strain is applied crosswise of the grain. It has, however, been found by experiment that when a tensile strain is applied to a bar of iron or other material, it is stretched a certain amount in proportion to the length of the bar and to the degree of strain to which it is subjected. If this strain does not exceed about one-fifth of that which would break the bar, it will recover its original length, or will contract after being stretched, when the strain is removed. The greatest strain which any material will bear without being permanently stretched is called its *limit of elasticity*, and so long as this is not exceeded no appreciable permanent elongation or "set" will be given to iron by any number of applications of such strains or loads. If, however, the limit of elasticity is exceeded, the metal will be permanently elongated, and this elongation will be increased by repeated applications of the strain until finally the bar will break. At the same time the character of the metal will be altered by the repeated application of strains greater than its elastic limit, and it will become brittle and less able to resist a sudden strain, and will ultimately break short off. It is therefore unsafe to subject iron, or, in fact, any other material, to strains greater than its elastic limit. This limit for iron boiler-plates may be taken at about one-fifth its breaking, or, as it is called, *ultimate* strength. It should be remembered, however, in this connection, that it often happens that the steam pressure is not the greatest force the boiler must withstand, as sudden or unequal expansion and contraction are probably more destructive, to locomotive boilers especially, than the pressure of the steam.

QUESTION 195. *What is the relative strength of wrought-iron and mild steel plates?*

Answer. Good wrought-iron boiler-plates have a tensile strength of about 50,000 lbs. per square inch, and mild steel about 60,000 lbs.

QUESTION 196. *What are the most important qualities which boiler-plates should possess?*

Answer. The first quality to be sought for in a boiler-plate is strength. This does not necessarily imply the mere power to resist being torn asunder by a dead weight, as in a testing machine, but the quality to withstand, without injury, the many and varying shocks and strains it is exposed to in the boiler-shop and in actual work. Many inferior plates exhibit as great a cohesive strength as those of better quality, their inferiority consisting in their brittleness or shortness, want of "body" or soundness, imperfect manufacture, and uncertain character or quality. Toughness and ductility combined with great tenacity, and also closeness and uniformity of texture and constancy of quality, are the properties and character to be sought for.*

QUESTION 197. *What qualities should boiler-plates and rivets have?*

Answer. All iron plates of the *best* quality should have a longitudinal tenacity of not less than 50,000 lbs. per square inch of section, and an ultimate elongation before breaking of about 12 per cent., and if not exceeding 1 in. in thickness, should bend double along or across the fiber when red hot, and if $\frac{7}{8}$ in. thick and under, they should bend double when cold without fracture.

Good iron plates should bend cold, without fracture, to the following angles:

Thickness of Plate.	Along the Fiber.	Across the Fiber.
¼ inch	90 degrees	55 degrees.
⅜ "	80 "	45 "
½ "	70 "	35 "
⅝ "	55 "	25 "
¾ "	40 "	20 "
⅞ "	30 "	15 "
1 "	20 "	10 "
1 "	15 "	7 "

The radius of the corner over which the plates are bent should not exceed half an inch.*

Steel boiler-plates should have a tensile strength of about 60,000 lbs. per square inch, and it should not be less than 50,000 nor more than 70,000 lbs., and when broken under tension the ultimate elongation of a test piece 8 in. in length, after fracture, should be not less than 20 per cent. of the original length. Strips not less than 2 in. broad and 10 in. long, cut from plates *not* exposed to the fire in service, should bear bending cold without fracture until the sides are parallel at a distance from each other of not less than three times the thickness of the plate. Strips taken from plates which, in service, will be exposed to the fire, should be heated, before bending, to a cherry red, then plunged into water of about 80° temperature, and kept there until of the same temperature as the water. They should then stand the same test required for the pieces which are bent cold.

The material of which rivets are made should have a high degree of ductility. A good iron rivet, cold, should bend double without fracture, and its head should flatten out by hammering when hot to about ¼ in. thick without fracture or fraying at the edge. A hot rivet-shank, when flattened down to a thickness equal to about one-half its diameter, should bear a punch driven through it without fracture at the hole.*

The steel of which rivets are made should always be of the mildest—that is, the most ductile material, because if it is not of this character they are liable to become hard and brittle while being worked and in use.

The resistance of steel rivets to shearing should therefore not be greater than that of iron rivets, or about 50,000 lbs. per square inch of section.

QUESTION 198. *Why should the greatest strength steel plates and rivets not exceed a certain limit?*

Answer. Because steel of a very high tensile strength is usually brittle and liable to fracture, whereas soft ductile steel usually has a comparatively low tensile strength.

QUESTION 199. *How are boiler-plates fastened together?*

Answer. By rivets which are made with a head on one end, and which are inserted red hot in holes, which are drilled or punched in the plates, and another head is then formed by hammering, or by steam, or hydraulic pressure, on the other end of the rivet. The rivets are thus made to fill the holes, and in cooling contract and draw the plates together.

QUESTION 200. *What is the strength of riveted seams compared with that of the solid plate?*

Answer. The strength of a riveted seam depends very much upon the arrangement and proportion of the rivets; but with the best design and construction, the seams are always weaker than the solid plates, as it is always necessary to cut away a part of the plate for the rivet holes, which weakens the plate in two ways: 1. By lessening the amount of material to resist the

* A force exerted to pull any material apart is called a *tensile strain*, and if exerted to compress it is called a *compressive strain*.

† It should be explained that in the process of manufacturing iron by rolling, the iron is stretched out into fibers in the direction in which it passes between the rolls.

* Wilson's Treatise on Steam Boilers.

strains. 2. By weakening that left between the holes. The first cause of weakness is obvious from an inspection of an ordinary seam, riveted with a single row of rivets, fig. 118. In this we have two plates $7\frac{1}{2}$ in. wide and $\frac{3}{8}$ thick fastened with

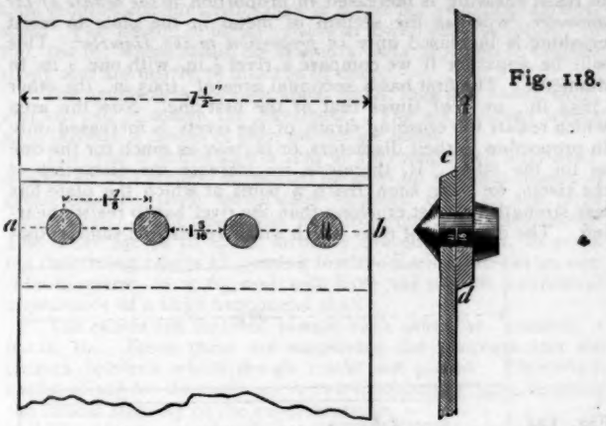


Fig. 118.

four rivets $\frac{11}{16}$ in. in diameter and $1\frac{7}{8}$ in. from center to center. The section of the plate calculated with decimals * would therefore be $.375\times7.5=2.81$ square inches. A piece $\frac{11}{16}$ in. wide and $\frac{3}{8}$ in. thick would be removed to form each hole, or a sectional area for the whole plate of $.375\times.6875\times4=1.03$ square inches, so that the section of the plate would be reduced through the holes $2.81-1.03=1.78$ square inches. In other words, on the dotted line *a b* it will have only about 63 per cent. of the sectional area of the solid plate.

The second cause of the reduction of strength is owing to the injury sustained by the plates during the process of punching. The knowledge existing regarding this subject is not very satisfactory, although numerous experiments have been made to determine the exact amount of weakening caused by punching plates. It is, however, certain that in many cases the strength of the metal *left* between the holes of boiler-plates is reduced from 10 to 25 per cent. by the process of punching. It is probable, however, that soft ductile metal is injured less than that which is harder and more brittle. Some kinds of steel plates are especially liable to injury from punching. It is also probable that the condition of the punch, and the proportions of the die used with it, have much to do with its effect upon the metal.

QUESTION 201. *How can the injury done to boiler-plates by punching be prevented?*

Answer. It has been shown that the injury to plates from punching is confined to a narrow area around the hole, and that by punching the hole smaller than required and then reaming it or drilling it to the required size the weakened portion of the plate is removed, leaving that portion between the holes equal, or, as has been shown in some experiments,† of greater strength than the original plate. It has also been shown by some experiments that annealing steel plates after punching restores them to their original strength; but with the mild steel now made there is little need of this precaution, and there is, perhaps, more danger of damaging the plates by careless attempts at annealing than by deterioration of metal in punching.

QUESTION 202. *How may a boiler seam like that shown in fig. 118 break?*

Answer. It may break in three different ways:

1. By a plate tearing between the rivet holes on the line *a b*.
2. By the rivets shearing off.
3. By the plate in front of the rivets crushing, as shown in fig. 119, or splitting the plate at right angles to the seam, as shown in fig. 119*a*.

QUESTION 203. *How can the strength of a boiler seam be calculated at each of these three points?*

Answer. The strength through the rivet holes is calculated by TAKING THE AREA IN SQUARE INCHES OF THE METAL WHICH IS LEFT BETWEEN THE RIVET HOLES, AND MULTIPLYING IT BY THE ULTIMATE STRENGTH OF THE METAL AFTER THE HOLES ARE MADE. Thus, in fig. 118, the area of each of the plates between the rivet holes is 1.78 square inches. As already stated, good iron boiler-plate will break at a strain of about 50,000 lbs. in the direction of its fibers.* The calculation for the strength through the holes would therefore be: $1.78\times50,000=89,000$ lbs. If the holes are punched and not afterward reamed or drilled the strength of the plates, as already explained, would

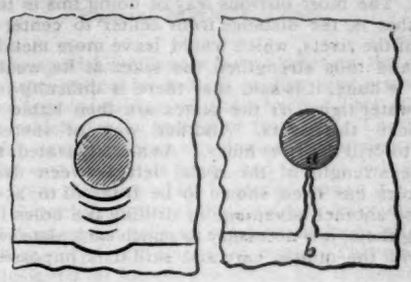


Fig. 119. Fig. 119a.

be considerably reduced, and a lower tensile strength must be used in calculating the strength of the seam.

It has also been found by experiment that the strength of rivets to resist shearing is about the same as that of good boiler-plate to resist tearing apart, or 50,000 lbs. per square inch. The strength of the rivets, therefore, is calculated by MULTIPLYING THE AREA IN SQUARE INCHES OF ONE RIVET BY THE NUMBER OF RIVETS, AND THE PRODUCT BY THE STRENGTH OF THE METAL TO RESIST SHEARING. The calculation for fig. 118 would therefore be:

$$\text{Area of } \tfrac{11}{16} \text{ rivet} = .3712\times4\times50,000=74,240,$$

or somewhat less than the strength of the plates through the holes.

The resistance offered by a plate to the crushing strain of a rivet has been found also by experiment to be about 90,000 lbs. per square inch. It can be proved that the area which resists the crushing strain of a rivet in a plate, fig. 118, IS MEASURED BY MULTIPLYING THE DIAMETER OF THE RIVET BY THE THICKNESS OF THE PLATE. The calculation for the strength of this part of the seam will therefore be: diameter of hole $=.6875\times.375\times4\times90,000=92,812$.

The strength of the solid plate without any holes in it would be EQUAL TO ITS SECTIONAL AREA MULTIPLIED BY 50,000 LBS., or $7.5\times.375\times50,000=140,625$ lbs. The ultimate strength of our seam would then be as follows:

Rivets	(shearing) =	72,240 lbs.
Plates through rivet holes	(tearing) =	89,000 "
Plates in front of rivets	(crushing) =	92,812 "
Solid plate	(tearing) =	140,625 "

It will thus be seen that the strength of the weakest part of the above seam, fastened with a single row of rivets, is very little more than half (51.3 per cent.) of that of the solid plates. It will be noticed that the plates between the holes have an excess of strength over the rivets, which is desirable, because the plates are liable to more or less injury from punching.

QUESTION 204. *What are the usual proportions for single-riveted lap seams?*

Answer. The following table gives the usual proportions for such seams:

SINGLE-RIVETED LAP JOINTS.

Iron Plates, Iron Rivets.			Steel Plates, Iron Rivets.		
Thickness of Plates.	Diameter of Rivets.	Pitch of Rivets.	Thickness of Plates.	Diameter of Rivets.	Pitch of Rivets.
$\frac{5}{16}$ inch.	$\frac{11}{16}$ inch.	$1\frac{11}{16}$ inch.	$\frac{5}{16}$ inch.	$\frac{11}{16}$ inch.	$1\frac{9}{16}$ inch.
$\frac{3}{8}$ "	$\frac{3}{4}$ "	$1\frac{3}{4}$ "	$\frac{3}{8}$ "	$\frac{3}{4}$ "	$1\frac{5}{8}$ "
$\frac{7}{16}$ "	$\frac{13}{16}$ "	$1\frac{13}{16}$ "	$\frac{7}{16}$ "	$\frac{13}{16}$ "	$1\frac{11}{16}$ "
$\frac{1}{2}$ "	$\frac{7}{8}$ "	2 "	$\frac{1}{2}$ "	$\frac{7}{8}$ "	$1\frac{3}{4}$ "
$\frac{9}{16}$ "	$\frac{15}{16}$ "	$2\frac{1}{16}$ "	$\frac{9}{16}$ "	$\frac{15}{16}$ "	$1\frac{13}{16}$ "
$\frac{5}{8}$ "	$1\frac{1}{16}$ "	$2\frac{1}{8}$ "	$\frac{5}{8}$ "	$1\frac{1}{16}$ "	$1\frac{7}{8}$ "
$\frac{11}{16}$ "	$1\frac{1}{8}$ "	$2\frac{3}{16}$ "	$\frac{11}{16}$ "	$1\frac{1}{8}$ "	$1\frac{15}{16}$ "
$\frac{3}{4}$ "	$1\frac{3}{16}$ "	$2\frac{5}{16}$ "	$\frac{3}{4}$ "	$1\frac{3}{16}$ "	2 "
1 "	$1\frac{5}{16}$ "	$2\frac{7}{16}$ "	1 "	$1\frac{5}{16}$ "	$2\frac{1}{16}$ "

QUESTION 205. *Is the maximum strength of seams the chief aim in designing a boiler?*

Answer. No; a tight joint is of the first importance, for should leakage occur corrosion may soon alter any carefully calculated proportions of the respective sections in the joint. Indeed, it may be affirmed that in the majority of cases the safety of a boiler depends, in the long run, more upon the tight-

* In the following calculations all the dimensions have for convenience been reduced to decimals.

† See a description of Tensile Tests of Iron and Steel Bars, by Peter D. Bennett, in the Proceedings of the Institution of Mechanical Engineers, for February, 1886.

* Boiler-plates should always be so arranged that the greatest strain will come on them in the direction of their greatest strength, which is parallel with the fibers of the metal.

† This is the diameter of the rivets before being driven; the holes are usually made $\frac{1}{16}$ in. larger.

ness than the actual strength of the joints, since a large factor of safety is usually allowed.*

QUESTION 206. *How may a single-riveted lap seam be made stronger than that illustrated by fig.* 118?

Answer. The most obvious way of doing this is to increase the *pitch*—that is, the distance from center to center—and the diameters of the rivets, which would leave more metal between the holes, and thus strengthen the seam at its weakest part. But if this is done, it is said that there is difficulty in keeping the seam water-tight, as the plates are then liable to spring apart between the rivets. Another way of increasing its strength is to drill the rivet holes. As already stated, the difference in the strength of the metal left between drilled and punched holes has been shown to be from 10 to 25 per cent. There is also another advantage in drilling the holes for rivets. In punching them, it is necessary to punch each plate separately, and even with the utmost care and skill it is impossible to get

Fig. 120.

Fig. 121.

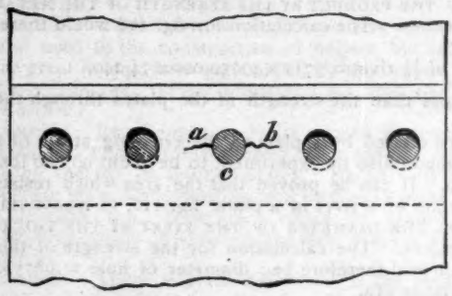


Fig. 122.

the holes to match perfectly. Some of them will overlap each other, as shown in fig. 120, so that when the rivet is set, it will assume somewhat the form shown in fig. 121. There is then danger that those rivets which fill the holes that match each other will be subjected to an undue strain. If, for example, we have five rivet holes, as shown in fig. 122, and only the center ones correspond with each other, then the rivets in all the other holes will assume somewhat the form shown in fig. 121, and therefore the center rivet *c*, in fig. 122, which fits the holes accurately, must take the strain of the other four until they draw up "to a bearing." Under such circumstances, which are not unusual, there will be great danger either of shearing off the rivet *c*, or of starting a fracture in the plates, as indicated by the irregular line *a b*, between the adjoining rivets. It is also obvious that a rivet like the one in fig. 121 will not hold the plates together so well as one which fits more perfectly, as shown in section in fig. 118, and therefore there is more danger of leakage between the plates from badly fitted rivets than from those which fill the holes more perfectly; consequently rivets which fit imperfectly must be placed nearer together than those which are well fitted. It is true that rivets which are set with a riveting machine fill any inaccuracies of the holes more perfectly than those which are set by hand. But even if they are made to fill the holes as shown in fig. 123 they are still not so strong to resist shearing nor so efficient in

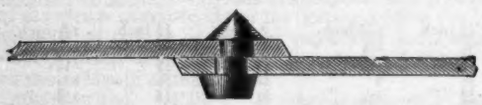
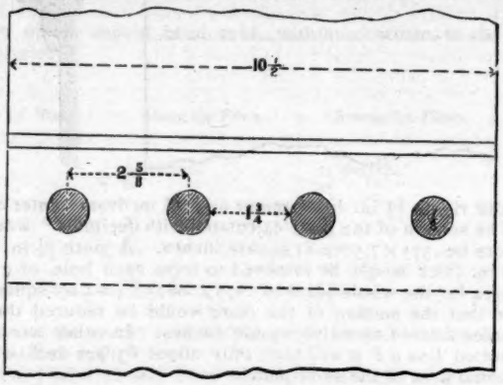


Fig. 123.

holding the plates together as they would be if the holes conformed more perfectly to each other. In drilling the holes, the second plate can be drilled from the holes in the first, so that the holes in each one will correspond with the other perfectly. The rivets will therefore fit more accurately, and consequently can be spaced further apart, and still keep the plates tight, and thus there will be more material between the holes, which is the weakest part of the seam. It has been shown that a rivet $\frac{11}{16}$ in. in diameter has a resistance to shearing of 18,560 lbs. There is therefore no advantage with plates $\frac{5}{8}$ in. thick in spacing such rivets further apart than $1\frac{13}{16}$ from center to center, because the metal of 50,000 lbs. of tensile strength which is left between drilled holes that distance apart would be slightly stronger than the rivets. If therefore the rivets are placed further apart, their diameter must be increased. There is, however, a limit beyond which the diameters of rivets cannot be increased with advantage, because if we increase their diameters, their sectional area to resist shearing is increased in proportion *to the square of the diameter*, whereas the section of metal in the plate to resist crushing is increased only *in proportion to the diameter*. This will be apparent if we compare a rivet $\frac{1}{2}$ in. with one 1 in. in diameter. The first has a sectional area of .1963 in., the other .7854 in., or *four* times that of the first one. Now the area which resists the crushing strain of the rivets is increased only in proportion to their diameters, or is *twice* as much for the one as for the other. If, therefore, we increase the diameters of the rivets, we very soon reach a point at which the plate has less strength to resist crushing than the rivet has to resist shearing. The diameter of rivet which will give just the same resist-

Fig. 124.



ance to both strains varies with the thickness of the plates; with $\frac{5}{8}$-in. plates a $\frac{1}{2}$-in. rivet will have a resistance to shearing of 30,065 lbs. and the plate in front of it a resistance to crushing of 29,530 lbs. A $\frac{1}{2}$-in. rivet is, therefore, the largest size which can be used to advantage in $\frac{5}{8}$-in. plates. If now we were to space such rivets so far apart that the metal left between the holes would have a strength just equal to that of the rivets, we would have the strongest possible seam that can be made with a single row of rivets. This distance would be $1\frac{3}{4}$ in. between the edges of the rivets, or $2\frac{5}{8}$ in. from center to center, as shown in fig. 124. The following table will show the strength of such a seam composed of four rivets, and two plates $10\frac{1}{2}$ in. wide,* with drilled holes:

Plates through rivet holes	(tearing)	118,125 lbs.
Rivets	(shearing)	120,260 "
Plates in front of rivets	(crushing)	118 125 "
Solid plates	(tearing)	196,875 "

From this it is seen that the strength of the seam with drilled plates is 60 per cent. of that of the solid plates, or it is about $18\frac{1}{2}$ per cent. stronger than that made with plates having punched holes and the rivets nearer together. It should be noted that a great part of the superiority of the seams made with drilled holes is due to the superior accuracy of the work done in that way, which makes it possible to use larger rivets spaced further apart. It is probable that with the use of some recently designed machines, intended to produce greater accuracy in punching rivet holes, part of the above advantage may be realized with that kind of work. The greatest distance that rivets may be spaced apart without incurring danger of leakage between the plates must, however, be determined more by practical than theoretical considerations. It is certain, however, that rivets may be spaced much further apart than they are in ordinary practice, and the seams still be kept tight, if the work is done with sufficient accuracy and care.

(TO BE CONTINUED.)

Manufactures.

The Proposed Hudson River Bridge.

THE plan for a bridge over the Hudson River, advocated by Mr. Gustav Lindenthal before the American Society of Civil Engineers, is described by Mr. Lindenthal himself as follows:

"The proposed North River Bridge is for six railroad tracks on a floor platform 86 ft. wide (same as East River Bridge); clear height at middle of river, 145 ft. above high tide at 50°

* Wilson's Treatise on Steam Boilers.

* It has been necessary to take for an illustration plates of a different width from the preceding example, in order to get an even number of spaces between the rivets in each case.

Fah. temperature (the floor would sink 4 ft. in summer and rise about the same in winter). Length of middle span, 2,850 ft., to centers of towers, each pier within the legal pier-line of each shore. The end spans are about 1,500 ft. long each, and the total length between anchorages is 6,500 ft., including anchorages. The height of metal towers to lower cable is 400 ft.; to top, 500 ft., which stand on masonry piers 340×180 ft. respectively and are nearly 75 and 180 ft. deep.

"The anchorages are each about 320 ft. long and 180 ft. wide, and are 210 ft. above the pavement. The six railroad tracks pass through a tunnel in each anchorage mass.

"The type of the bridge is that of two suspended huge arch-ribs (or braced arches) supported on steel or wrought towers of great stability, from which they descend back to the large anchorages, which resist the pull from the large arch-cables. The latter are 50 ft. apart, strongly braced together, to resist the deforming effects of passing loads. Each cable has an outside diameter of 4 ft., and will have the smooth cylindrical appearance of a huge bent-metal shaft.

"The cables are inclined toward each other, or 'cradled,' 1 ft. in 10. From them are suspended the platform and the trusses, between which the six tracks are placed. Four wind-cables of 12½ in. diameter are in two horizontal planes, securing the lateral stability of the superstructure.

"The towers are strongly braced inside with heavy members, and on outside with large-sized lattice-filling between the curved columns. On top the arches are held apart by a heavy cross-bracing. The towers are connected solidly at the top and bottom into one coherent structure.

"The architectural features of the bridge were considered of the highest importance and were sought to be obtained in a natural manner without attempts at ornamentation.

"The bridge is to be proportioned for six heavy trains, 1,500 ft. long each, drawn by two of the heaviest known engines. It is not likely that six such trains would meet on the bridge in a lifetime. Ordinarily the loads will only be a small fraction of the assumed maximum.

"The bridge will be proportioned against a wind pressure of 56 lbs. per square foot on all exposed surfaces. The principal provision for it are two wind-trusses (forming the top and bottom of suspended track platform) combined with four wind-cables, each 12½in. diameter and kept under constant tension by a lever arrangement in towers.

"Each cable is surrounded with a steel mantle ¼ in. thick, leaving an air-space between it and the wire cable inside. All connections with web members will be adjustable during and after erection, so that both cables shall be equally strained from the uniform loads of the superstructure at a middle temperature.

"Cost of bridge alone, about $15,000,000. Time of building, 3½ years.

"A bridge with a middle pier would be more expensive on account of depth of foundation and the impracticability of using wire cables for more than one middle span. The great strength of wire as compared with metal in link-cables makes the longer span bridge cheaper.

"The rigidity of the bridge will be such that all trains will be able to cross it at fast speeds (same as on solid ground) without causing any discernible oscillation."

Marine Engineering.

THE Lockwood Manufacturing Company, East Boston, Mass., is building two large steam dredges to be used on the Cape Cod Canal.

THE activity of shipbuilding on the lakes is shown by the statement that at the Wheeler yard in Bay City, Mich., there are 10 new vessels on the stocks, ranging in size from 700 to 2,000 tons register.

ENGLISH papers report greater activity in shipbuilding and more new orders than for some time past. Recent contracts include two new steamers of 5,000 tons each for the Peninsular & Oriental Company and several other steamers of large size.

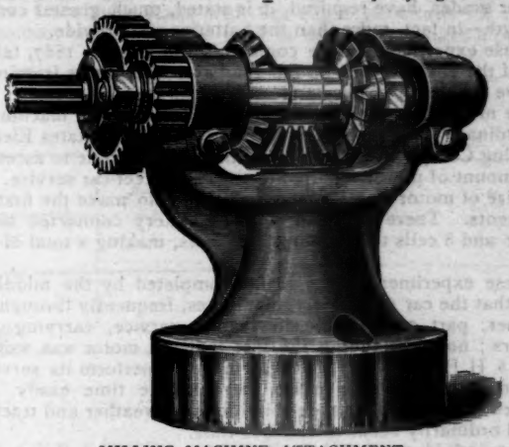
THE Pusey & Jones Company in Wilmington, Del., recently completed a revenue cutter for the Republic of Colombia, South America. The *Marine Journal* describes the vessel as follows: "*La Popa* is an iron vessel, and is the third of her exact class built by the said company within the past few years. She is 120 ft. long on the 8-ft. water line; 20 ft. beam, moulded; 10 ft. 4 in. deep, from top of cross-floors to top of deck-beams amidships, and is sheathed to 9-ft. water line with yellow pine 2½ in. thick, secured through plating by ¾-in. bolts, and covered with copper sheathing metal. Rigged as a fore-and-aft schooner, and provided with a six-pounder Hotchkiss rapid-firing gun of the most improved type. Vessel driven by a vertical direct-acting, surface-condensing engine, 24 in. diameter, 36-in. stroke; boiler of the Scotch type, 9 ft. 10 in. diameter, 12 ft. long, constructed for a working pressure of 60 lbs. per square inch."

Special Machine Tools.

AMONG the special appliances recently put on the market are a portable arrangement for heating, setting, and removing locomotive tires without taking off the wheels. This consists of a furnace in which gas is generated from oil. The gas is conveyed under pressure from an air-pump to a ring or circular tube pierced with numerous holes, and the tire is heated by the jets of gas from this ring which is placed around it.

Messrs. Pedrick & Ayer, of Philadelphia, have also recently completed a universal milling machine of large size, which is adapted to a very great range of work. This machine was specially designed for locomotive shops, but is adapted for general use. It weighs 6,000 lbs., and much work can be done on it with greater precision and to better advantage than on a planer.

For use with this large milling machine an attachment has been devised which is shown in the accompanying cut. This



MILLING MACHINE ATTACHMENT.

attachment is cast hollow, and is secured to the head of the milling machine by four bolts. The base has an annular T-slot and a hole to insert the bolts.

It is driven by a socket fixed in the spindle of the milling machine, which is key-seated to fit the keyed stud in the attachment. Through the medium of a pair of miter wheels, this stud drives a spindle at right angles to the vertical attachment. This spindle is geared with a shaft in line with it, which is utilized as a cutter or saw arbor for cutting racks, sawing up stock, etc. This shaft runs in Atlas bronze bearings, and can be removed from the attachment by means of the two clamp screws in the clamp bearings.

This attachment can be used either vertically, horizontally, or at any angle around the center, the base being graduated to register its position. Cutter arbors or boring bars can be used in either end of the main spindle. For rack cutting there is no limit as to length, while for boring or milling castings of irregular shape or troublesome to hold in other tools, it will be found very useful. In cutting large gears the cutter spindle is placed vertically and the index head at right angles to the platen. The gear blank is then fed in line with the main spindle of the milling machine. By setting the platen at an angle, bevel gears may be cut. Spur gears up to 6 ft. in diameter can be cut with this attachment in connection with the heavy milling machine referred to above.

Electric Street Railroad Service in Boston.

THE New England Weston Electric Light Company, of Boston, has fitted up an ordinary street railroad car, No. 54 on the Cambridge Division of the West End Street Railroad, of Boston. In doing this it has used a motor built by the United States Electric Lighting Company, of New York, and employs 120 cells of the Julien storage battery. The method of connecting the battery to the motor and the axle is the invention of Mr. William L. Stevens, the electrician of the Weston Company.

The motor is specially wound to adapt it to the service of street traffic. The same batteries run also seven 16-candle power incandescent lamps and two electric bells, the bells being to serve as signals between the conductor and driver, and conductor, passen-

gers, and driver. These lights and bells are all run from the same batteries. The manipulation of the car is made by means of a vertical standard and hand-wheel on the forward platform, leaving the rear platform clear for passengers.

This hand-wheel and standard are readily transferred from end to end of the car, as may be desired.

The reversing gear is operated from either platform, and the car can be run backward in case a switch is missed or for any other cause. This can be done also without removing the hand-wheel.

The speed of the car is controlled *entirely* by this single hand-wheel—stopped, started, or slowed. The ordinary hand-brake is used only to hold the car while standing on an incline.

One of the practical difficulties with former experiments upon the use of storage batteries for street-car propulsion has been that the batteries could not endure the strain and deliver the amount of current necessary to do the work on the car used in Boston. The efficiency of the motor used, however, appears to have reduced the amount of current required to the practicable capacity of storage batteries now in the market.

Various grades up to and including 8 per cent. have been surmounted by this car without reaching 30 Ampères. The best results heretofore obtained, doing this same work, on even lighter grades, have required, it is stated, much greater current strength—in fact, more than the batteries can provide.

These experiments were commenced in March, 1887, taking one of the existing cars on the road and altering its framing to receive the motor battery and other apparatus.

The motor first used was a 5 H.P. shunt-wound machine of the ordinary type, manufactured by the United States Electric Lighting Company. At that time they were unable to ascertain the amount of power required to perform street-car service, and this size of motor was adopted with which to make the first experiments. There were 96 cells of battery connected to the motor and 8 cells to the lamps and bells, making a total of 104 cells.

These experiments were so far completed by the middle of June that the car ran, at irregular times, frequently through the summer, part of the time in regular service, carrying passengers; notwithstanding the fact that the motor was worked up to 8 H.P. frequently, it never failed to perform its service; carried its passengers, made the schedule time easily, and climbed the hills under such conditions of weather and track as would ordinarily occur in summer time.

These trials continued until the latter part of September, 1887, at which time a larger motor of 10 H.P., with enough additional cells to make a total of 120, was put into the car and all the appliances made in a more permanent manner than during the earlier experiments. One series of these experiments was to determine whether it were best that the motor should be connected to one or both axles, the final determination being to connect both axles, thus getting the traction of four wheels instead of two. Notwithstanding the fact that under various conditions of track from mud, ice, snow, and dirt, the car has been able easily to do its work.

The car is now supplied with Tripp anti-friction bearings, manufactured by the Hancock Inspirator Company, Boston.

Experiments have been made to ascertain what maximum speed is necessary for making the average schedule time, and the conclusion has been arrived at that a maximum speed of 10 miles an hour is sufficient and as high as it is safe to run in cities, though this car has been run at 12 miles an hour.

If in places a higher speed would be required or safe, there is a considerable reserve that could be easily applied.

It requires a personal observation of the performance of the car in crowded streets to appreciate the ready control which the driver possesses over the movement of the car around curves, switches, grades, up-hill and down, to improve the opportunities to pass between teams without danger of collision. This car may be stopped on curves or up grades, and started with facility.

The motor used on this car can be also employed where the power is taken from overhead or conduit conductors, as well as from storage batteries.

The Meneely Rolling Bearings for Cars.

THE Meneely Bearing Company, of West Troy, N. Y., has had for some time a new roller bearing in use on one of the trains running on the Albany & Troy belt line trains of the Delaware & Hudson Canal Company. A comparative test was made on November 24, 25, 26, 28, 29, and 30 last of two trains running on this line. Each train consisted of one combination (smoking and baggage) and two eight-wheel passenger cars, but one train throughout was on the Meneely steel rolling bearings (Gibbons' patent), and the other on ordinary bronze bearings. To secure a uniform test, the same engine was used on both trains. The results are reported as follows:

	1. Meneely Bearings.	2. Ordinary Bearings.
Weight of train	159,850 lbs.	154,100 lbs.
Motive power required to start (dynamometer test).	563 lbs.	2,433 lbs.
Distance run (24 round trips)	360 miles.	360 miles.
Coal consumed (anthracite)	15,600 lbs.	18,800 lbs.
Water evaporated	12,081 gals.	14,130 gals.
Engine under working pressure (120 lbs)	20 hours 2 min.	19 hours 40 min.

The saving of coal by the use of the Meneely bearings was thus 17 per cent., or 18 per cent. if the greater weight of train be allowed for. The saving of water was 15 per cent. Of the coal used in running train No. 1 about 94 per cent., it is claimed, was used in running the engine alone; on train No. 2 only 78 per cent. was thus used.

The peculiarity of the Meneely bearing is that the separation of the rollers is effected by means of freely revolving balls. These balls perform no other function and sustain no weight. It is claimed that the independent action of these parts and the avoidance of rigid spacing frames and similar devices constitute the superiority of this over roller bearings previously tried, as they permit flexibility of movement as well as solidity of construction.

Proceedings of Societies.

American Society of Civil Engineers.

A REGULAR meeting was held at the Society's House in New York, December 21. It was announced that the annual business meeting would be held January 18. An invitation to hold the annual convention (in July next) in Milwaukee was presented.

On January 19 various points of interest about the city would be visited, and among them the new bridge crossing the Harlem River, to which the Society was invited by the engineers in charge.

A paper on the Venturi Water Meter, by Clemens Herschel, was then read. This meter is an instrument making use of a new method of gauging water, applicable to the cases of very large tubes, and of a small value only of the liquid to be gauged.

An interesting discussion followed, which was participated in by Messrs. Flagg, Church, Emery, Streidinger, Cross, Brinckerhoff, North, and Brush, the general opinion being that the new device promised to be of great value.

A REGULAR meeting was held at the Society's house in New York, January 4. Mr. Gustav Lindenthal, of Pittsburgh, read a paper on the Hudson River Bridge Problem, with a discussion on Long Span Bridges. The paper described a plan for building a suspension bridge across the Hudson River, for the purpose of bringing the railroad lines terminating on the New Jersey shore into New York City. The site proposed for the bridge was near 14th Street, and the writer's plan provided for a suspension bridge with two steel towers, one on each shore, about 500 ft. high. The bridge would be in three spans, the central span being 2,850 ft. from center to center of the towers, and the shore spans about 1,500 ft. each. After describing the details of the plan, the writer treated briefly of the different elements of construction, and closed by a short discussion on the arch and cantilever types of bridges.

THE ANNUAL MEETING.

THE annual meeting was held at the Society's House in New York, January 18. In the morning the reports of the officers were read. The proposed amendments to the constitution (which we have already referred to) were discussed. They will be submitted to letter-ballot.

In the evening Lieutenant Charles C. Rogers, U. S. N., read a long and interesting paper on the Panama Canal in 1887.

January 19 the members made a visit to the new bridge under construction over the Harlem River, going to the spot in a steamboat. In the evening the usual reception was held at the Society's House.

The officers elected for the ensuing year are: President, Thomas C. Keefer, Montreal; Vice-Presidents, J. James R. Croes, New York, and Robert Moore, St. Louis; Secretary and Librarian, John Bogart, New York; Treasurer, George S. Greene, Jr., New York; Directors, Mendes Cohen, Baltimore;

Joseph M. Wilson, Philadelphia; Charles B. Brush, Hoboken, N. J.; Stevenson Towle, Alphonse Fteley, New York.

Master Car-Builders' Association.

LIST of subjects, with the committees appointed to report thereon, at the Annual Convention of the Master Car-Builders' Association, to be held at Alexandria Bay, N. Y., June 12, 1888:

1. *Standards and Appliances for the Safety of Trainmen* (this Committee was instructed to report some definite recommendations next year).—H. Hegewisch, U. S. Rolling Stock Co., 35 Wall St., N. Y.; John Kirby, Lake Shore & Michigan Southern, Cleveland, O.; M. N. Forney, 45 Broadway, New York.

2. *Automatic Freight-Car Brakes.*—Godfrey W. Rhodes, Chicago, Burlington & Quincy, Aurora, Ill.; George Hackney, Atchison, Topeka & Santa Fé, Topeka, Kan.; B. Welch, Central Pacific, Sacramento, Cal.; John S. Lentz, Pennsylvania & New York, Packerton, Pa.; W. T. Hildrup, Harrisburg Car Co., Harrisburg, Pa.

3. *The Best Form and Construction of Car Roofs.*—J. D. McIlwain, Grand Trunk (G. W. Div.), London, Ont.; Samuel Irvin, Missouri Pacific, St. Louis, Mo.; L. Packard, New York Central & Hudson River, West Albany, N. Y.; William Forsyth. Chicago, Burlington & Quincy, Aurora, Ill.

4. *Car Heating.*—Frank L. Sheppard, Pennsylvania, Altoona, Pa.; R. D. Wade, Richmond & Danville, Washington, D. C.; Robert Miller, Michigan Central, Detroit, Mich.

5. *Wheels* (this Committee was appointed to confer with a Committee appointed by wheel manufacturers).—J. N. Barr, Chicago, Milwaukee & St. Paul, Milwaukee, Wis.; John Kirby, Lake Shore & Michigan Southern, Cleveland, O.; George F. Wilson, Minneapolis & St. Louis, Minneapolis, Minn.

6. *Journal Lubrication, and the Best Practice for Economizing Oil.*—J. W. Cloud, New York, Lake Erie & Western, Buffalo, N. Y.; H. Roberts, Chicago & Grand Trunk, Detroit, Mich.; J. N. Lauder, Old Colony, Boston, Mass.

7. *The Best Form of Door Hangings, including Grain Doors.*—E. W. Grieves, Baltimore & Ohio, Baltimore, Md.; John P. Levan, Pennsylvania, Altoona, Pa.; John Voorhees, Indianapolis Car Manufacturing Co., Indianapolis, Ind.

8. *How Can Uniformity in the Interchangeable Parts of Cars be Obtained.*—Samuel Irvin, Missouri Pacific, St Louis, Mo.; James McGregor, Michigan Car Co., Detroit, Mich.; John Hodge, Chicago, Santa Fé & California, Streator, Ill.

9. *Committee of Arbitration in Disputed Cases under the Rules of Interchange.*—William Buchanan, New York Central & Hudson River, Grand Central Depot, New York; Robert C. Blackall, Delaware & Hudson Canal Co., Albany, N. Y.; G. W. Cushing, Philadelphia & Reading, Reading, Pa.

10. *Subjects to be Reported at the next Annual Convention for Investigation and Discussion at the Succeeding Convention.*—Joseph Wood, Pennsylvania Co., Pittsburgh, Pa.; William McWood, Grand Trunk, Montreal, Canada; E. B. Wall, Pittsburgh, Cincinnati & St. Louis, Columbus, O.

11. *Committee of Arrangements for the Next Annual Convention.*—R. C. Blackall, Delaware & Hudson Canal Co., Albany, N. Y.

CIRCULAR FROM SPECIAL COMMITTEE OF THE EXECUTIVE COMMITTEE ON AUTOMATIC FREIGHT CAR COUPLERS.

The Special Committee of the Executive Committee, appointed to consider in detail the matter of Automatic Freight Car Couplers in accordance with the type adopted by the Association, desires to have the opinion of the members of the Association upon the following matters:

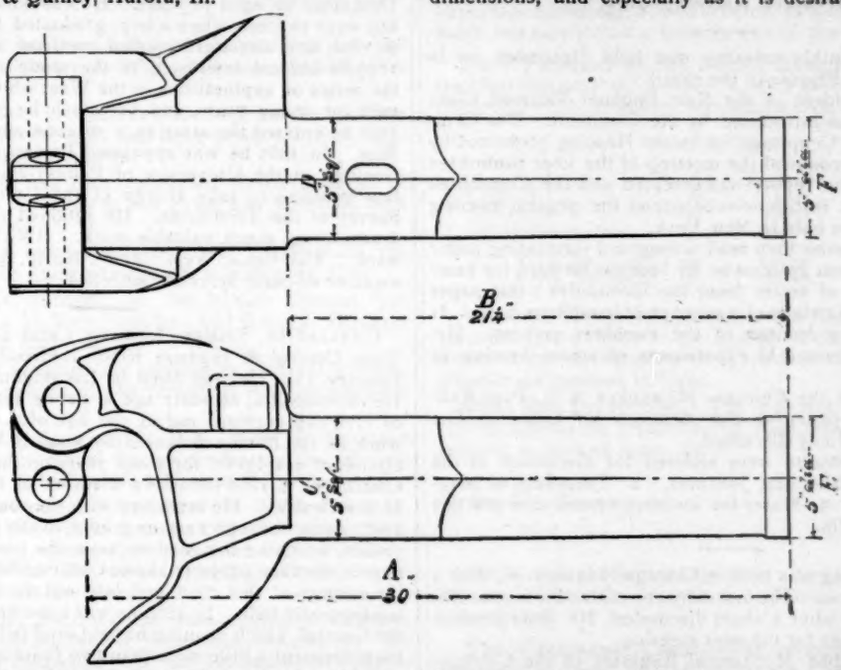
1. The length of the drawhead from the end which bears against the follower-plate to the inside face of hook when closed; marked *A* in the engraving.

2. The length of drawhead from the end which bears against the follower-plate to the face of the horn for striking against end sill; marked *B* in the engraving.

3. The dimensions of drawhead in cross section at the stirrup which carries it; marked *C* and *D* in the engraving.

4. The dimensions in cross section at the end which bears against the follower-plate; marked *E* and *F* in the engraving.

The cuts hereon show the dimensions indicated on the latest Janney freight car coupler, and inasmuch as other freight car couplers have been made with but slight variations on these dimensions, and especially as it is desirable to have a pretty



long shank for the drawhead, in order to balance the weight at the outer end, it is the opinion of the Committee that the dimensions as shown on this cut are desirable dimensions to establish as a standard.

Enclosed are two circulars and an envelope addressed to the Secretary. You are requested to alter the figures in one of the circulars to such as you would recommend, if other figures seem preferable; otherwise, to signify that the figures are satisfactory, sign it and mail as promptly as convenient to the Secretary, so as not to delay the decision of this important matter.

The Committee takes this opportunity to call your attention to a further recommendation, not with a view to secure immediate action, but to enable the members of the Association to be prepared to discuss and vote upon it at the next convention. They consider that dead-blocks should be used with the Master Car-Builders' Standard Coupler. If the dimensions shown on the card are adopted, the dead-blocks should be 9 in. long, measuring lengthwise of the car, and the draft-springs have 2-in. action.

The dead-blocks can be placed 22 in. between centers, as provided by the standard of the Association, provided that the lower face is not less than 38 in. from top of rail when car is empty. As the standard for this height is given at 36 in. by the Association, your Committee recommend that this figure be increased to 38 in., to allow proper clearance for the new form of coupler.

EDWARD B. WALL.
JOHN W. CLOUD.
M. N. FORNEY, *Secretary.*

New England Railroad Club.

THE regular meeting of this Club was held in Boston, January 11, President Lauder in the chair. The subject for discussion was "Frogs and Safety Switches."

Mr. Richards opened the discussion with a historical sketch, speaking of the earliest forms of frogs used and of the original forms of switches. He spoke also at considerable length of the various safety switches introduced in latter years, of their merits and faults. He said that the frogs and switches on American roads have much greater service than abroad, owing to the greater weight of our cars.

The discussion was continued by Messrs. Patch, Clark, Lane, Ellis, Coleman, Davidson, and Lauder. Mr. Lane advocated the use of spring frogs. Mr. Ellis said that steel-rail frogs should alone be used where safety is required, and also mentioned the defects of a number of the so-called safety switches. Mr. Lauder spoke of the increased wheel-base of engines and trucks. Incidentally a good deal was said about the great increase of weight in locomotives in recent years, and the consequent increased wear of track.

The subject for the next meeting is Axles, Wheels, and their Relation to the Track.

Western Railway Club.

THE regular monthly meeting was held December 21 in Chicago, President Rhodes in the chair.

Mr. Lauder, President of the New England Railroad Club, was present, and was introduced by the President. The Committee on Standard Couplings for Steam Heating presented its report, giving an account of the meeting of the joint committee held in Buffalo. The report was accepted and the Committee was continued, with instructions to attend the general meeting on this subject, to be held in New York.

Mr. Willard A. Smith then read a long and interesting paper reviewing the different systems so far brought forward for heating cars by means of steam from the locomotive; this paper was illustrated by drawings of a number of couplings used. It was discussed by a number of the members present. Mr. Lauder gave an account of experiences of steam heating in Massachusetts.

Mr. J. N. Barr, of the Chicago, Milwaukee & St. Paul Railroad, then read a paper on Specifications for Cast-iron Car Wheels; this was briefly discussed.

The following subjects were selected for discussion at the next meeting: 1. Axles and Journals. 2. The effect of magnetism on watches. 3. Water for locomotive use, and practice in washing out boilers.

A REGULAR meeting was held in Chicago, January 18, with a very large attendance. The first subject—Axles for 60,000-lbs. Cars—was laid over after a short discussion, Mr. Barr promising to prepare a paper for the next meeting.

Mr. George A. Gibbs, Mechanical Engineer of the Chicago, Milwaukee & St. Paul, then read a long and interesting paper on Water for Locomotive Boilers, giving the result of some investigations carried on under his charge for two years past. He also described the practice of his road in washing out boilers.

This paper was briefly discussed by Messrs. Rhodes, Sinclair, F. C. Smith, Brown, Hickey, and Forsyth.

Mr. Herr's paper on Magnetism in Watches was postponed to the February meeting.

OBITUARY.

JOHN F. ANDERSON, who died January 1 in Portland, Me., was for many years one of the leading engineers of his native State. He made the surveys for nearly all the older lines in Maine, and had charge of the building of several, the latest being the Portland & Ogdensburg. For several years past he had been a member of the Railroad Commission.

GENERAL ISAAC R. TRIMBLE, who died in Baltimore, January 2, was one of the oldest living graduates of West Point. General Trimble was born in Virginia, and became second lieutenant, First Artillery, July, 1822; he resigned in 1832 to become Chief Engineer of the Baltimore & Susquehanna Railroad, now the Northern Central, and finished the road to York, Pa., in 1837. He entered the Confederate army in May, 1861, in which he performed distinguished service. Since the war he has lived in retirement.

JAMES WALSH OTLEY, who died in Des Moines, Ia., January 2, aged 68 years, was born in England and educated as a civil engineer by his father, who was Chief Engineer of the Stockton & Darlington Railroad. When 28 years old he came to this country, and eight years later settled in Keokuk, Ia. He made the surveys for the old Des Moines Valley Railroad and took charge of the construction of a large part of the road. After its completion he was Chief Engineer for several years. About 10 years ago he retired from active work. Mr. Otley was one of the pioneer engineers of Iowa, and was much esteemed throughout the State.

FREDERICK MERCUR, who died of typhoid fever at Wilkesbarre, Pa., January 11, aged 51 years, was for many years connected with the Lehigh Valley Railroad. He was, from an early age, employed as a surveyor and civil engineer in Eastern Pennsylvania. His first connection with the Lehigh Valley was as Assistant Engineer; afterward as Chief Engineer he built the extension from Penn Haven to Wilkesbarre. In 1867 he was placed in charge of the Lehigh Valley Coal Company's property as General Superintendent, and held that position till his death. He was considered high authority on all questions connected with mine engineering and coal mining.

DR. FERDINAND VANDERVEER HAYDEN died in Philadelphia, December 22, aged 58 years. He was born in Westfield, Mass., but went to Ohio when a boy, graduated from Oberlin College in 1850, and afterward studied medicine in Albany, N. Y. In 1853 he became interested in the study of geology and began the series of explorations in the West which continued at intervals for many years, and by which he is chiefly known. In 1861 he entered the army as a surgeon and served through the War. In 1865 he was appointed Professor of Mineralogy and Geology in the University of Pennsylvania, but in 1867 left that position to take charge of the United States Geological Survey of the Territories. He retained this position until his death, doing much valuable work. His chief published works were "The Great West" and "North America." He was a member of many scientific societies.

CHARLES H. FISHER, formerly Chief Engineer of the New York Central & Hudson River Railroad, died in New York, January 18. He was born in Lansingburg, N. Y., in 1835. He developed at an early age a strong taste for the profession of civil engineering, and at the age of seventeen commenced work on the Racine & Janesville Road in Wisconsin. He was afterward employed for some years on the repairs of the Erie Canal, and in 1860 became a member of the engineering staff of the Central. He remained with the road until the spring of 1868, rising through various grades to the position of First Assistant, which he resigned to take the position of Chief Engineer of the then projected Lake Ontario Shore Road. He made the surveys of that road, and laid out the line on which it was subsequently built. In 1869 he was appointed Chief Engineer of the Central, which position he held until failing health compelled his retirement a little more than two years ago. He built the two additional tracks of the road, the stations at Albany, Syracuse, and Buffalo, and a number of bridges. His last work was the elevation of the tracks and the new station in Rochester. Mr. Fisher was a conscientious and hard-working engineer, always giving the closest attention to his work. The sickness which compelled his retirement and finally caused his death was probably the result of overwork and anxiety.

PROFESSOR BALFOUR STEWART, who died at Balrath, Ireland, December 19, aged 59 years, was a distinguished English authority on physical science. He was born in Scotland and educated at the Scotch universities of St. Andrews and Edinburgh. In 1859 he was appointed to the directorship of the Kew Observatory, and in 1867 to the secretaryship of the Meteorological Committee, which last appointment he resigned on his promotion to the Professor's chair of Natural Philosophy in Owens College, Manchester, in the year 1870, a post which he held until his death. Two years before this distinction was conferred upon him he had been awarded the Rumford medal by the Royal Society for his discovery of the law of equality between the absorptive and radiative powers of bodies. Together with Messrs. De la Rue and Loewy he wrote "Researches on Solar Physics," and he and Professor Tait published their researches on "Heating produced by Rotation in Vacuo." Besides these he wrote a number of treatises, especially on the subjects of meteorology and magnetism. The article in the *Encyclopædia Britannica* on "Terrestrial Magnetism" is from Professor Balfour Stewart's pen. Among the many works of which he was sole or joint author may be men-

tioned the "Elementary Treatise on Heat," "Lessons in Elementary Physics" (1871), "Physics" (1872), "The Conservation of Energy" (1874), and "Practical Physics" (1885). Most of these are text-books on the subjects of which they treat. He and Professor Tait also produced the "Unseen Universe," a work of which 12 editions have been published. At the time of his death he was President of the Physical Society of London, and was a member of the committee appointed to advise the Government on solar physics.

PERSONALS.

W. E. CHAMBERLAIN resigned his position as General Superintendent of the South Atlantic & Ohio Railroad on January 1 last.

D. H. BARRETT has been appointed Chief Chemist in charge of the Baltimore & Ohio Railroad laboratory at the Mount Clare shops, Baltimore.

GENERAL A. ANDERSON, formerly Chief Engineer of the Northern Pacific Railroad, is now Vice-President of the Buffalo, Rochester & Pittsburgh Railroad Company.

Mr. R. MONTFORT, heretofore Resident Engineer, has been appointed Chief Engineer of the Louisville & Nashville Railroad.

G. B. HAZLEHURST has been appointed Engineer of Bridges and Tests of the Baltimore & Ohio Railroad, with office in Baltimore.

LIEUTENANT EDMUND L. ZALINSKI, the well-known inventor of the pneumatic dynamite gun, has been promoted to be Captain in the United States Artillery.

Mr. J. R. GROVES has been appointed Superintendent of Rolling Stock of the St. Louis & San Francisco Railroad, with office in Springfield, Mo.

R. E. BRIGGS has been appointed Chief Engineer of the Denver & Rio Grande Railroad, with office in Denver, Col.

JAMES C. CLARKE, formerly of the Illinois Central, has accepted the position of Vice-President and General Manager of the Mobile & Ohio Railroad.

R. E. RICKER has resigned his position as General Superintendent and Chief Engineer of the Denver & Rio Grande Railroad.

G. H. WORCESTER, late on the Lake Shore & Michigan Southern, has been appointed Superintendent of the Harlem Division of the New York Central & Hudson River Railroad.

C. M. BISSELL is now Superintendent of the Mohawk & Hudson Division of the New York Central & Hudson River Railroad, which, as newly arranged, includes the main line from New York to De Witt. He has for a long time been Superintendent of the Harlem Division.

COLONEL T. M. R. TALCOTT has been appointed Commissioner of the Southern Railway & Steamship Association. He was for many years connected with the Richmond & Danville Railroad, but for two years past has been Vice-President and General Manager of the Mobile & Ohio. Few men could be found so well fitted for his new position as Colonel Talcott; he has always been a close student of traffic questions, and no one, probably, is better acquainted with Southern railroad business. Colonel Talcott's reports, when he was in charge of the Richmond & Danville, were models, deserving study by all railroad managers.

NOTES AND NEWS.

The French Navy.—A report of considerable interest has just been prepared by M. Menard Dorian upon the French Navy. According to this report, the French marine comprises 386 vessels of all kinds, viz.: 18 first-class ironclads, 19 ironclad cruisers, 9 ironclads used for coast guard purposes, 4 ironclad gun-boats, 1 ironclad floating battery, 9 battery cruisers, 9 first-class cruisers, 11 second-class cruisers, 15 third-class cruisers, 15 first-class dispatch boats, 31 second-class dispatch boats, 16 dispatch boats, also available for transport purposes, 8 dispatch boats, also available as torpedo boats, 16 unarmored gun-boats, 12 chaloupes, each carrying a gun, 11 steam chaloupes, 10 torpedo boats for the open sea, 62 first-class torpedo boats, 41 second-class torpedo boats, 7 vedette torpedo boats, 10 first-class transports, 10 second-class transports, 4 third-class transports, 13 sailing ships, 29 ships used for fishing protection purposes, and 3 training ships.

The French marine has been engaged during 1887 upon the construction of no fewer than 92 vessels, viz.: 8 first-class ironclads, 4 ironclad gun-boats, 1 ironclad cruiser, 2 battery cruisers, 3 first-class cruisers, 2 second-class cruisers, 6 third-class cruisers, 1 torpedo gun-boat, 3 dispatch boats, 2 torpedo dispatch boats, 54 other torpedo boats, 3 dispatch boats, also available as transports, 1 transport, properly so called, and 2 sailing frigates. In the course of 1888, further new vessels will be undertaken to an estimated cost of $9,200,000.

Casting a Large Steel Gun.—An experimental gun of steel was cast January 11 at the works of the Pittsburgh Steel Casting Company in Pittsburgh. Several months have been passed in making tests and experiments and in preparing the mould. The cast was made in the presence of the Government steel inspectors now on duty in Pittsburgh. The gun is of Bessemer steel, and the mould was made on the Rodman plan. The charge of iron in the converter was 16,500 lbs., and the time occupied in making the blow was about 30 minutes. Only two minutes were required to pour the metal into the mould. The whole operation of making the gun was in charge of Mr. Hainsworth, Superintendent of the works.

The company is also to bore out the gun, and has had special machinery put in for that purpose. When finished it will be of 6-in. bore, will be 16 ft. 1½ in. long, and will weigh about 5½ tons.

Should the gun meet successfully the Government tests, an important advantage will be secured, as a cast gun is necessarily much less costly than a built-up gun of the same size.

Blast Furnaces of the United States.—The condition of the blast furnaces on January 1, with their weekly capacity, is reported by the *American Manufacturer* as below:

Fuel.	In blast.		Out of blast.	
	Number.	Capacity.	Number.	Capacity.
Charcoal	73	13,237	100	11,692
Anthracite	117	35,259	83	19,984
Bituminous and coke	151	92,224	63	29,344
Total, Jan. 1, 1888	341	140,720	246	61,020
Total, Jan. 1, 1887	332	127,660	256	60,446

As compared with the previous month (December), the January statement shows little or no change in charcoal and anthracite furnaces, but a reduction of 1,070 tons in the capacity of the bituminous furnaces in blast.

Steel Rail Production.—The American Iron & Steel Association reports the production of steel rails in 1887 and 1886 as follows, in tons of 2,000 lbs.:

	1887.	1886.
First half-year	1,154,193	707,447
Second half-year	1,141,401	1,042,452
Total, year	2,295,594	1,749,899

Of the total production last year, 1,239,115 tons were made in Pennsylvania, 722,651 tons in Illinois, and 333,828 tons in other States.

The Nicaragua Canal.—The steamer *Hondo*, with the engineering party for the Nicaragua Canal survey, arrived at San Juan del Norte (Graytown), Nicaragua, in due season, and work was begun at once. The headquarters of Chief-Engineer Peary were established on San Francisco Island, at the junction of the San Francisco River with the San Juan, where permanent quarters will be provided. Besides the headquarters party, there are six parties in the field; five of these are assigned to divisions along the San Juan River, and the sixth is the hydrographic party, which is surveying the harbor of Greytown and the proposed entrance to the canal. The surveys are to be very carefully made, and minute records will be kept.

The Stabler Foundry.—The sons of the late Edward Stabler, of Sandy Spring, Md., have presented to Swarthmore College the foundry of their father, with all its appliances and patterns. In this foundry was cast all the metal work of the presses and seals made by him for the various State and city governments, corporations, and courts of law throughout the country; for the several departments of the national Government at Washington, and for its consular agents all over the world. Here, too, were made the steel dies for the gold and silver medals of the Maryland Institute, and many other works of a similar character. This valuable gift will become a part of the foundry of the department of engineering and the mechanic arts at the College, and will add largely to the means of instruction in this direction.

The Barbed Wire Fence Patent.—The United States Circuit Court for the District of Northern Iowa, in a suit by the Washburn & Moen Company against manufacturers at Cedar Falls, has decided that the Glidden patent, under which

the suit was brought, is not valid. This decision was based upon evidence submitted to the Court to the effect that as early as 1859 one Alvin Morley, of Delaware County, Ia., had mounted a wire fence with a barb formed substantially in the same manner as described in the Glidden letters patent; that a panel of this fence was exhibited at a county fair held in Delhi, Delaware County, in 1859, and that Morley constructed within two or three years afterward several pieces of fence of this description in the neighborhood. It is also claimed that between the years 1860 and 1873 several other fences with barbs of similar construction were put up by others in Delaware County.

The witnesses included several persons who had seen the fence at the time stated and a blacksmith who had made for Morley a rude machine for bending the barbs. A specimen of the barbed wire made in 1859 was also shown. Morley, it appeared from the evidence, was a man of much mechanical ability, but very eccentric, and he finally died in a lunatic asylum.

The courts have heretofore sustained the Glidden patent, this decision being the first one against it. The case will undoubtedly be appealed to the Supreme Court.

The Pennsylvania Railroad Employés' Benefit Fund.—The Pennsylvania Railroad Company has followed the example of the Baltimore & Ohio by adding to its employés benefit fund a savings fund arrangement. Under an order recently issued any employé of the company can make deposits with agents designated by the company; these agents are well distributed over the company's lines, so as to be accessible to all. On all such deposits interest at the rate of 4 per cent. yearly will be allowed. Depositors can draw their money from any of the agents on giving 10 days' notice. Interest not drawn will be added to the principal yearly.

New Russian Railroad Work.—Notwithstanding Russia's financial difficulties, it is understood that the Minister of Finance will agree to the request of the Minister of Ways and Communication to provide the sum of $3,750,000 toward double-tracking sections of the principal Russian railroads. The sections selected are: On the Petersburg-Warsaw Railroad, from Toroshino to Pskoff; on the Moscow-Brest, from Smolensk to Viazma; on the Koursk-Azoff, from Slairansk to Lozovoi; and on the Kozloff-Voronez, from Kozloff to Griazi. On all these railroads traffic is rapidly increasing, and other sections will have a second line laid down as soon as funds will allow of it. The Minister of Ways and Communication has also asked for credit for $1,500,000 for the Transcaucasian Railway, in order to enable it to increase its rolling stock running between the Caspian and Batoum. It is anticipated that the failure of the maize crop in America will cause a very heavy demand for maize in the Caucasus, where vast quantities are grown. Another application has also been made by the Minister for a credit to enable him to start the Murom-Kazan Railroad, which is intended to connect the important Volga town of Kazan with the Russian system. The line will eventually be carried on from Kazan to Perm, and join the railroad running thence from Perm to Ekaterinburg, thereby completing the Northern Siberian line as far as that point. In regard to the Southern Siberian Railroad from Samara to Ufa, the track is announced to have been leveled throughout, and a considerable mileage of rails laid down. A large bridge over the River Bieli will be constructed the first thing in the spring; the piers are already nearly complete, and it is hoped that by the following winter the line will be open for traffic. Altogether, in spite of the Minister of Finance declaring in his budget at the beginning of the year that the building of railroads would be stopped, there would appear to be more activity than ever.—*Engineering.*

Copper Production of the United States.—The production of copper in the United States in 1887, according to the *Engineering and Mining Journal*, was as follows, in tons of 2,240 lbs.:

	Tons.
Lake Superior Region	33,330
Montana	35,223
Arizona	8,036
Colorado	893
Other States and Territories	1,090
Lead smelters	555
Total from native ores	79,107
From foreign ores	2,366
Total	81,473

The principal feature of this statement is the increase of the Montana production. The output from that Territory last year exceeded that of the Lake Superior Region, formerly the chief copper-producing district in the country. The Arizona output also increased largely last year.

Of the Montana product the Anaconda mines alone turned out 25,446 tons, exceeding by 5,092 tons the output of the Calumet & Hecla Company, once the leading producer.

Electrical Subways in New York.—The Board of Electrical Control, which is charged with the work of putting the electric wires in New York underground, has presented a report for the year 1887, the substance of which is as follows:

The report reviews the work of the old Subway Commission very briefly and explains the relations of the construction company known as the Consolidated Telegraph & Electrical Subway Company to the Board. This company is simply authorized to build the subways designed by the Commission and to rent space in them to the electric companies on fair and impartial terms, to be approved by the Board. The Department of Public Works has full control over all excavations made by the company, and its profits are limited to 10 per cent. on the money actually invested, any excess going to the city, and its books and accounts are subject at all times to inspection by the Comptroller. The Commission considers that every safeguard for the interests of the city has been provided in its contract with the Construction Company.

The work of building subways was resumed as soon as the new Board was organized, in July, 1887, and at the close of the working season 189,918 ft. of trench had been excavated for the laying of subways. Of single ducts for telegraph and telephone service 903,180 ft. had been constructed, besides 4,050 ft. for distributing service and connections to central stations. The average capacity of each duct is estimated at 80 wires, making the total capacity of the subways for telephonic and telegraphic service 72,254,400 ft., or about 13,700 miles of wire. For arc lighting and power service 254,250 ft. of single duct have been laid, capable of accommodating nearly 500 miles of wire, and for incandescent lighting 186,745 ft. of conduit has been built, carrying 560,235 ft. of conductors. It is claimed, on the strength of these figures, that the capacity of conduit already provided in the city by the Board of Electrical Control is considerably greater than is now provided in any other city in the world, so far as the Board is informed.

On all the streets where conduits have been constructed the companies whose wires have been provided for have been notified to remove their poles and wires from the surface within 90 days, and if they do not comply with the order ample provision is made in the law by which the local city authorities may proceed to remove the obstructions. The Western Union Company has already about 500 miles of wire in the conduits, the Metropolitan Telephone & Telegraph Company has about 1,000 miles, and the Edison Company more than 100 miles under ground. These companies, with the Brush and others, are preparing to enter the conduits at many points, and if the local authorities act energetically with the Commission when the 90 days of notice has expired, many of the streets must necessarily be freed soon from the dangerous and unsightly pole systems.

The actual number of poles already removed from the streets as a result of the work of the Board is 217. Many more poles could have been removed had the wires of the Fire and Police Departments been provided for by the city authorities. The Board has no control over these wires, and cannot order down the poles supporting them.

Very little progress has been made by the Board in making and enforcing regulations for the continuance of the wires overhead where this is necessary, either before the subways are completed or in connection with them after they are built. The Board has adopted some rules to minimize the danger from electric light wires, but owing to the lack of inspectors, who cannot be employed until some certain provision for their payment is made, few improvements have been made in the condition of the overhead system, and little attention is paid by the companies to the rules and regulations established by the Board.

The Board has constructed subways in different localities differing greatly in design to accommodate the wants of the companies and the nature of the locality. The Commission holds that liberty of choice under certain restrictions should be liberally accorded to the companies for whose service the subways are intended, and it has acted on this principle. In the matter of additions to the conduits for the purpose of making local connections this same liberality has been shown, the Board allowing the Construction Company to furnish whatever the several companies desire for themselves from the manholes to the points desired to be reached. A system of inspection of the subways and the wires within them and their maintenance free from moisture and gases is being devised; but in this, as in other matters, the Board is seriously embarrassed by the lack of funds. An appropriation for the pay of inspectors is asked for.